CAMPBELL'S

OPERATIVE ORTHOPEDICS

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CONTENTS

VOLUME II

CHAPTER XIII

CHAPTER XIV

CHAPTER XV

CHAPTER XVI

CHAPTER XVII

PAGE

CHAPTER XVIII

CHAPTER XIX

CHAPTER XX

CHAPTER XXI

CHAPTER XXII

PAGE

COLOR PLATES

CAMPBELL'S

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Volume II

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Volume II

The etiology of chronic synovitis, as defined above, is often obscure In some cases, the cause may be presumed to be an infectious agent, although cultures from the joint may be negative. During World War II chronic synovitis in one or both knees was not uncommonly observed three weeks following an acute gonorrheal urethritis Although the urethritis had cleared with the use of penicillin this would lead one to believe the lesion of the knee was of gonorrheal origin In every case however the synovitis was of a subacute or chronic type, and organisms could not be recovered from the joint. Similar cases of chronic synovitis have followed the subsidence of acute purulent lesions of joints which were treated with penicillin In these fluid in the joint, associated with a chronic proliferative lesion of the synovial membrane, persisted for weeks after cultures of the fluid were found negative

Also during the war it was observed that too early mobilization and too early weight bearing on knee joints after removal of semilunar cartilages, or after operations for other traumatic lesions of the knee, apparently caused a condition similar to the infectious lesion this entity was presumed to be traumatic in origin The slight degree of fever occasionally associated and the local inflammatory changes in the joint at times suggested the possibility of a post operative infection which was kept at a low grade by the administration of sulfa drugs or penicillin

Inge made the following note in regard to the pathologic changes in the synovial membrane, as demonstrated by microscopic sections Whatever the cause of the inflammation whether rheumatoid arthritis, infectious synovitis, or chronic trauma and regardless of what the clinical result of the operation may be *the pathologic changes in the synovial membrane are basically the same* in all cases. They consist fundamentally first of hypertrophy and hyperplasia of the synovial layer of cells, so that this membrane is grown into large villi and redundant folds, and second of thickening of the subsynovial layers by edema fibrosis, enlargement of blood vessels and scattered foci of round-cell infiltrations. Any one of these features may predominate in any given knee joint but all are usually present in every case with remarkable similarity even in cases of osteoarthritis and of synovial osteochondromatosis. The round cell infiltration is usually perivascular and characterized by the presence of large numbers of plasma cells, thus simulating the histologic appearance of certain syphilitic lesions. In any attempt to correlate the histologic picture with the end result of the operation or to base a prognosis on the appearance of the microscopic section there has been a complete lack of success. Two sections which appear identical under the microscope may come from patients whose clinical courses differ completely

Since the knee is the most common site of chronic synovitis, discussion of the treatment is limited to this joint. The indications for operation are a thickened capsule and synovium with an increase in intra-articular fluid which fail to respond to conservative treatment. A persistent swelling of the joint with fluctuation but without edema of the external soft parts is characteristic and may be detected both visually and on palpation It is assumed that the possibility of a tuberculous synovitis has been ruled out prior to operation

If the synovitis is infectious and a part of a systemic infection the original focus should be eliminated Conservative treatment should be given an adequate trial before surgery is undertaken. The ordinary conservative measures should be supplemented by the administration of penicillin both parenterally and into the joint and by fever therapy The latter is most easily induced by

voluntary control which usually is three to four weeks postoperatively, wal is permitted with the aid of a drop ring catch or control dial knee brace. the beginning the knee is held rigid in the brace the range of motion i creased gradually according to the reaction of the joint to weight bearing



Fig 574 —Specimen of hypertrophied synovial membrane and semilunar cartilages remo synovectomy



Fig. 575.—A Case I double exposure, showing range of flexion and extension follo synovectomy No other joints involved. B Case II range of flexion following synovect Pathology in knee joint associated with progressive polyarticular or atrophic type of arth Disease process practically quiescent in all joints.

voluntary control, which usually is three to four weeks postoperatively walking is permitted with the aid of a drop ring catch or control dial knee brace. In the beginning the knee is held rigid in the brace the range of motion is increased gradually according to the reaction of the joint to weight-bearing If

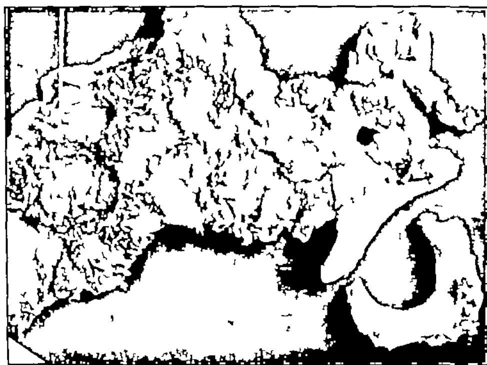


Fig 574 —Specimen of hypertrophied synovial membran and semilunar cartilages removed by synovectomy

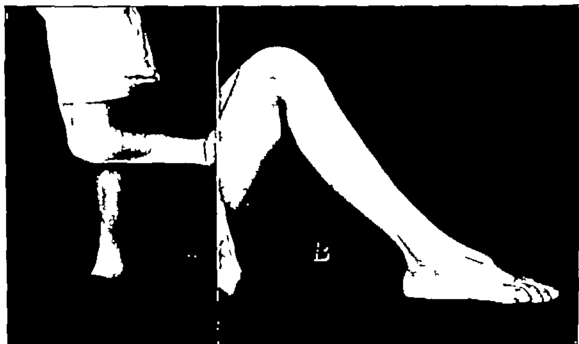


Fig. 575.—*A* Case I double exposure, showing range of flexion and extension following synovectomy No other joints involved. *B* Case II range of flexion following synovectomy Pathology in knee joint associated with progressive polyarticular r atrophic type of arthritis. Disease process practically quiescent in all joints.

after two or three weeks of exercises the range of motion in the joint is not more than 30 degrees, one is justified in manipulating the joint under general anesthesia

Following synovectomy, the joint should be sufficiently free of pain to allow the average amount of walking without discomfort, and should have at least 70 degrees of motion In some cases, motion may approach normal Synovectomy can never be counted upon to increase the range of motion in a joint

ATROPHIC (RHEUMATOID) ARTHRITIS

Atrophic arthritis is characterized by progressive polyarticular ankylosis. Although all the joints may not be completely fused function will be impaired to some extent in practically all those involved Operative treatment is limited chiefly to the lower extremities and as in other low grade affections, is instituted preferably after all acute symptoms have subsided Since however the active process may continue indefinitely, even for years, operative treatment is at times advisable while the disease is in the progressive or active stage the joints themselves may act as foci from which other joints may be invaded When the disease is rapidly progressive early fusion of several of the joints may limit the process relieve pain, and preserve the joint in a satisfactory position for use If advisable arthroplasty may be carried out at a later date

Despite efficient splinting during the active stage of the disease, deformity is a common sequela of atrophic arthritis. In some cases, correction can be secured by apparatus alone in others, the deformity can be only partially corrected by apparatus, surgical procedures as described in the chapter on Ankylosis and Deformity being necessary to complete correction

This is a systemic disease and, in many cases, the patient is a poor surgical risk his ability to undergo several long and elaborate operations definitely limited. When multiple operations are contemplated, therefore, frequently one must of necessity select some procedure which is less desirable from the standpoint of ultimate function, yet may be accomplished rapidly without excessive shock to the patient.

ATROPHIC ARTHRITIS OF THE TOES

Clawtoes may be associated with many affections, but as a rule are most severe and fixed in atrophic arthritis. The deformity is characterized by hyperextension of the metatarsophalangeal joints and flexion or extension of the distal phalangeal joints Dorsal contracture of the toes may be so extreme that the phalanges are dislocated dorsally on the metatarsal bones. The heads of the metatarsal bones are excessively prominent on the soles of the feet.

Adequate correction is seldom obtained unless the osseous structures are shortened sufficiently to relax the contracted soft tissues. For deformities of mild or moderate degree the measures described in Chapter XXII are applicable For extreme fixed clawtoe deformity wherein correction is impossible by procedures limited to the soft tissues, we usually employ a modification of an operation devised by Hoffman of St. Louis, in 1911 This technic embodies removal of all the heads of the metatarsal bones. By shortening the osseous structures, the contracted soft tissues are relaxed sufficiently to allow correction of the deformity Theoretically this removes an important weight bearing sur

face of the foot but practically the results have been satisfactory in atrophic arthritis. This technic is not recommended for ordinary clawtoes.

Technic—Longitudinal incisions are made between the distal ends of the second and third metatarsal bones, between the fourth and fifth metatarsal bones, and over the first metatarsophalangeal joint respectively The fascia is divided longitudinally and retracted, together with the extensor tendons, to expose the heads of the bones Through linear incisions over the metatarsophalangeal joints, the head and neck of each metatarsal bone are di vested of all soft tissue attachments The heads of the second, third fourth, and fifth metatarsal bones (and rarely the first) are removed with a portion of the neck sufficient to permit release of the contracted tissues and free motion between the bases of the phalanges and the remainder of the metatarsal bones. Tenotomy of the tendons is unnecessary as they are relaxed by shortening of the metatarsal bones. The great toe is preferably corrected by a procedure which preserves a weight bearing surface (see clawtoe deformity of the great toe Chapter XXII) No postoperative fixation is employed

ATROPHIC ARTHRITIS OF THE ANKLE

Unless the joint is carefully supported by proper splints, atrophic athritis of the ankle will be followed by an equinus deformity which rapidly becomes fixed. In equinus of long standing surgical correction is secured by lengthen ing of the tendo achillis and posterior capsulotomy (p 1018) If the joint is ankylosed, the osseous fusion is severed (p 1022) and after plastic procedures on the soft tissues, the foot is placed in the desired position.

ATROPHIC ARTHRITIS OF THE KNEE

In addition to surgical measures for correction of deformity the following operations are applicable to atrophic arthritis of the knee (1) synovectomy (2) arthroplasty or reconstruction, and (3) athrodesis.

Synovectomy

Synovectomy not only promotes local restoration of function, but is an adjunct to conservative measures in that infected material which may act as a focus is eradicated. The technic of the operation is described on page 839

The results which may be anticipated in polyarticular lesions are in no way comparable to those obtainable when the disease is confined to one joint. For example if both the knee and hip are affected synovectomy of the knee may be adequate, but passive and active motion of the knee may be restricted by pain within the hip Moreover in this type, there is a greater tendency to recur rence of symptoms, particularly when extensive degeneration of the articular cartilages or atrophic changes in the bone have taken place. Good results have been reported following 60 to 80 per cent of synovectomies performed during the quiescent period of atrophic arthritis. Swett reports success in a number of cases following synovectomy carried out during the progressive stage this, however has not been the experience of the majority of surgeons, and operation during the progressive period is not generally advised, as the outcome is ex tremely uncertain.

If pain beneath the patella is a predominant symptom and the articular surface of the patella manifests an extreme degree of chondromalacia patellectomy may be combined with synovectomy (p 849)

Arthroplasty and Reconstruction

In any procedure designed to break up ankylosis and increase the range of motion following atrophic arthritis, a more extensive resection of the joint surfaces is required than when ankylosis has been caused by acute infectious arthritis. In certain cases, arthroplasty (p 1069) or reconstruction (p 848) may effect some improvement however the prospect of restoring a permanent satisfactory degree of function by either method is always doubtful

Arthrodesis

After the disease has reached the quiescent stage, the joint may have a slight degree of motion. If this is sufficient to cause persistent pain, preservation of motion is not justified arthrodesis is the treatment of choice provided fusion cannot be accomplished by conservative measures.

ATROPHIC ARTHRITIS OF THE HIP

Operations for restoration of function of the hip joint following atrophic arthritis may, in many cases, simultaneously correct a fixed deformity Function may be restored to some extent by procedures similar to those employed following hypertrophic arthritis.

In the presence of bilateral ankylosis, stability may be sacrificed on one side in order to obtain a range of motion adequate for sitting even though full weight bearing on the operated hip is impossible. If arthroplasty or reconstruction of the hip is employed, several operations may be required before an appreciable degree of motion is obtained, as ankylosis is prone to recur For this reason, some authors state that Jones pseudarthrosis is particularly applicable to ankylosis of the hip following atrophic arthritis. The procedure should not be carried out on both sides, as the motion thus induced may be accompanied by pain and instability Further it is not admissible in children We have performed pseudarthrosis in a small series of cases, but with such poor results that the procedure has been abandoned

ATROPHIC ARTHRITIS OF THE SPINE

The flexion of deformities associated with atrophic arthritis or Marie-Strumpel arthritis of the spine may be so pronounced that the patient's field of vision is limited to a small area near the feet, thereby making walking extremely difficult Attempts have been made to correct these deformities either by multiple osteotomies or by manual osteoclasis. In view of the grave possibility of a neurologic catastrophe which would make a bad situation worse we believe either procedure is rarely indicated

ATROPHIC ARTHRITIS OF UPPER EXTREMITY

Smith Petersen and his colleagues have advanced some excellent reasons for surgery during the active stage of atrophic arthritis. Although the rest ' treatment is usually successful in alleviating pain and arresting the progress of the disease it is frequently followed by considerable loss of function This is true moreover not only of the joint primarily affected, but of the other joints in the same extremity which become secondarily affected Observing that secondary causes of pain about an arthritic joint of this type produce a chain of undesirable reactions in the entire extremity he advises

early surgical treatment of the secondary sources before destruction of the joint is so far advanced that restoration of function by surgical means is almost impossible

Regardless of whether one or all the joints in the upper extremity are involved protective muscle spasm is likely to produce adduction and internal rotation of the shoulder flexion deformity of the elbow accompanied by a decrease in pronation and supination and a flexion deformity of the wrist with ulnar deviation of the hand on the forearm Usually the fingers are also in a position of flexion and ulnar deviation. Since any one painful joint may cause secondary limitation of motion in other joints of the extremity Smith Petersen advises early mobilization of the primary joint and thus a return of function of the joints secondarily involved. With this in mind the surgeon must be on the alert for changes in pain or discomfort incident to the effects of the *primary lesion.*

ATROPHIC ARTHRITIS OF THE SHOULDER

Smith Petersen utilizes the shoulder joint to exemplify what he means by secondary causes of pain in joints primarily involved in atrophic arthritis. When the glenohumeral joint is the site of an active process, protective muscle spasm produces an adduction and internal rotation deformity of the joint. This muscle spasm affects not only the joint itself but also the bursae about the shoulder the bursae become involved in an inflammatory process. To a considerable extent motion between the scapula and thorax depends upon locking of the glenohumeral joint this, in turn increases tension on the subacromial bursa. An acutely painful lesion of the bursa will automatically eliminate scapulothoracic motion On the assumption that subacromial bursitis accompanying rheumatoid arthritis limits function of the shoulder and secondarily that of the entire upper extremity Smith Petersen has advocated an operation called acromioplasty for relief of the pain By apposing the central tendon of the deltoid muscle to the scapulohumeral tendinous cuffs, pain is relieved sufficiently to allow the patient to exert shoulder girdle motion and thereby compensate for the diminished motion in the scapulohumeral joint. Subsequent improvement in function of the shoulder joint leads to improvement in the other joints of the upper extremity

Acromioplasty (Smith Petersen) —The acromion is exposed by an S-shaped or a bayonet shaped incision which begins three-fourths inch anterior to the anterior angle of the acromion and extends to a point three-fourths inch behind the posterior angle of the acromion The periosteum between the insertion of the trapezius and the origin of the deltoid muscle is incised. The deltoid is then reflected laterally from the acromioclavicular joint to a point just medial to the posterior angle of the acromion thus exposing the subacromial bursa A tape or small sponge is placed beneath the acromion and the latter including the posterior angle, is excised, the acromioclavicular joint being left intact. Removal of this bony roof completely exposes the subacromial bursa providing easy access to the congested villi usually found covering the underlying tendinous cuff A synovectomy consistent with the extent of the disease process is then carried out In closure of the wound the periosteum to which the muscle is attached is reflected over an area extending from the acromioclavicular joint to the spine of the scapula by this means, the central tendon of the deltoid muscle is approximated to the periosteal attachment of the trapezius muscle

After Treatment.—(See p 1242.)

Smith Petersen reports that eleven patients for whom this operation was performed were relieved of pain, but did not obtain a striking increase in the range of motion in the glenohumeral joints that, in the majority improvement of motion in the shoulder girdle was responsible for the improved function In no case was the operation undertaken until rather marked changes had taken place in the glenohumeral joint He advises the operation however for subacromial bursitis associated with atrophic arthritis of the shoulder joint even though roentgenograms do not show advanced destructive changes in the joint

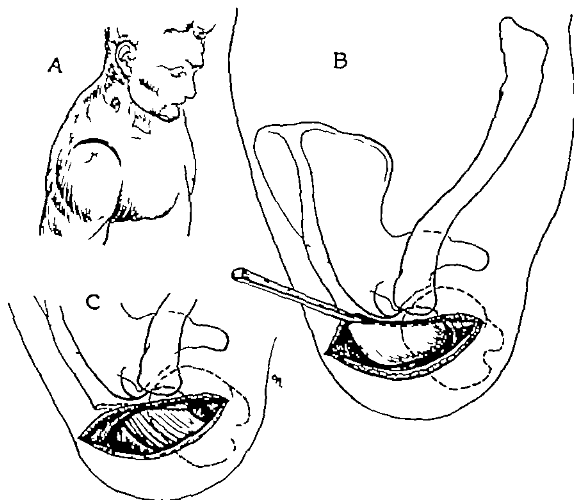


Fig. 576—Smith-Petersen acromioplasty *A*, Line of skin incision. *B* Deltoid muscle detached from acromion acromion divided with osteotome. *C* Acromion has been detached and the subacromial bursa resected to expose musculotendinous cuff.

ATROPHIC ARTHRITIS OF THE ELBOW

In atrophic arthritis of the elbow joint associated with limitation of flexion and extension and pronation and supination Smith Petersen has called attention to a common defect which may be responsible in some measure for the limited motion a malalignment or malrelationship between the head of the radius and the capitellum He has repeatedly found that the head of the radius is displaced anteriorly to such an extent that it cannot move properly in its normal mechanical relationship with the capitellum frequently a small defect, corresponding with the inferior articular margin of the radius, is present in the articular surface of the capitellum He attributes this displace-

ment to the protective spasm of the biceps muscle If this is true resection of the head of the radius should remove any rather pronounced mechanical blockage of the joint in flexion and extension as well as in pronation and supination. Resection of the head of the radius is usually accompanied by a more or less complete synovectomy of the elbow joint. If the process is extensive synovectomy should include the posterior compartment of the joint this is accomplished through a lateral incision (Fig 577) by reflection of the muscle attachments from the lateral condyle and the epicondylar ridge.

Smith Petersen has found that, although the range of motion in the elbow is not materially improved by this procedure there is a striking improvement so far as relief from pain is concerned The earlier the operation is perfomed the better the functional result.

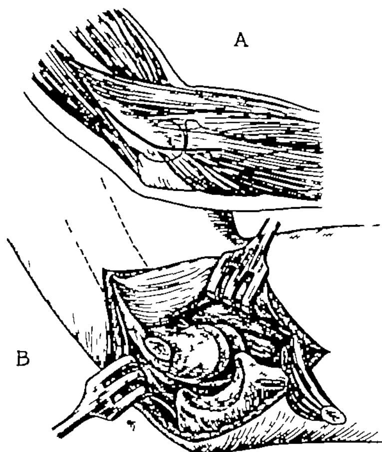


Fig. 577—Technic of excision of head of radius and synovectomy of elbow joint. *A* Line of skin incision. Subluxation of head of radius in relation to capitellum. *B* Joint exposed by reflection of common origin of extensor muscles. Head of radius resected.

Arthroplasty

Unlike the results of arthroplasty after ankylosis from pyogenic infection, the range of useful motion which may be expected following atrophic arthritis of the elbow is always doubtful, as ankylosis is prone to recur Nevertheless, the procedure is worth while, particularly if the shoulder and wrist are not affected, since the elbow may at least be placed in the position for maximum function should ankylosis recur

ATROPHIC ARTHRITIS OF THE WRIST AND FINGERS

If the wrist is ankylosed in acute flexion, resection of the proximal row of metacarpal bones (p 1049) may permit a practicable degree of motion. The wrist should always be immobilized in slight dorsiflexion in the event of recurrence of the ankylosis, the joint will be in the position most suitable for future function.

Synovectomy may be employed successfully in the metacarpophalangeal joints, especially that of the thumb when the other articulations of the hand and wrist are relatively normal The technic of synovectomy of the knee may in principle, be followed here

In 1940 Smith Petersen described a new approach to the wrist joint which was suggested by Darrach's resection of the ulna By resection of the distal end of the ulna the medial aspect of the joint is exposed, this presents a satisfactory area for arthrodesis. For atrophic arthritis he combines arthrodesis of the wrist and excision of the distal end of the ulna This is an improvement over the old dorsal type of arthrodesis in that supination and pronation are preserved and another possible source of pain the distal radio-ulnar joint is eliminated From his experience in a small group of cases, arthrodesis in conjunction with excision of the distal end of the ulna affords better results than resection of the ulna alone

HYPERTROPHIC ARTHRITIS

From a surgical standpoint hypertrophic arthritis may be classified as follows (1) A polyarticular degenerative process, which may be caused by infection or may be the natural outcome of systemic changes, as toxemia and impaired metabolism, accompanying advancing age Seldom is this type observed in persons under the age of thirty five years. The process is more or less active not only in the joint on which surgery is contemplated, but in others as well. (2) A monarticular affection the reaction in a joint to some process which has subsided leaving a mechanical incongruity Mechanical derangement, pyogenic infection, congenital anomaly, old coxa plana, epiphyseal separation and fracture into the joint, are among the common forerunners of this disability Monarticular affections offer a much better prognosis than polyarticular lesions, as the causative agent is no longer active or is eliminated

HYPERTROPHIC ARTHRITIS OF THE FOOT AND ANKLE

In the foot and ankle, arthritic changes associated with a generalized arthritis may produce symptoms of sufficient severity to warrant fusion More often however surgery is employed for a localized arthritis of static or traumatic origin, as observed in hallux valgus, hallux rigidus, pes planus, and malunited fractures of the ankle and tarsal bones, or following osteoarthritis, as in Köhler s disease These affections are discussed elsewhere

HYPERTROPHIC ARTHRITIS OF THE KNEE

Operative measures commonly employed for restoration of function in hypertrophic arthritis of the knee are (1) removal of loose bodies (2) excision of osteophytes, (3) synovectomy (4) reconstruction (5) arthroplasty (6) arthrodesis, and (7) patellectomy

Removal of Loose Bodies

Loose bodies in the knee, as demonstrated by the symptoms, physical examination, and roentgenograms, demand operative removal. Since trauma may be the cause of extrusion of osteophytes into the joints as loose bodies, a discussion of the surgical technic will be found in the chapter on Traumatic Lesions.

Excision of Osteophytes

Osteophytes are removed when of sufficient size and so located as to cause impairment of function. Roentgenograms may reveal extensive formations which impinge upon the joint surfaces, with resulting pain and disability Although the range of motion may be slightly increased by the excision, pain and disability usually continue on account of extensive degenerative changes of the articular surfaces Rarely if ever is this procedure alone advisable

Synovectomy

Occasionally an extensive and persistent proliferative synovitis, with all the characteristic changes, is associated with typical hypertrophic or osteoarthritis of the knee. If the pathologic process is practically confined to the synovium, with only slight changes in the osseous structures, synovectomy is the procedure of choice. If however there are marked hypertrophic and atrophic changes of the bone with narrowing of the joint space to such an extent that function without pain is improbable fusion or arthrodesis is indicated At the time of synovectomy extensive fibrillation of the cartilage may be observed especially over the point of greatest articular pressure. This area should be dissected out with a scalpel and the surface leveled to correspond as well as possible to the articular contour

If pain beneath the patella is a predominant symptom and the articular surface of the patella exhibits an extreme degree of chondromalacia, patellectomy may be successfully combined with synovectomy (p 839)

Reconstruction

We have not employed this procedure in a sufficient number of cases to warrant an accurate opinion as to its merit The same type of reconstruction in the hip has been wholly unsuccessful. Certainly it should be attempted only in carefully selected cases, i e., in young patients with an extensive monarticular affection. Even so a total fascial arthroplasty of the knee would appear to be more satisfactory if an operation of such magnitude seems indicated. If the procedure is used, the patient should be previously advised of the possibility that fusion may eventually be necessary

Technic (Magnuson)—Following a median parapatellar incision the joint is exposed and the patella retracted laterally thus bringing into view the entire anterior surface of the lower edge of the femur and a part of the upper surface of the tibia With a thin bladed chisel the exostoses are removed from both condyles, the edge of the synovial membrane being left attached. The degenerated cartilage is then shaved from the condyle down to cancellous bone, with care to remove all transverse ridges. Being usually wider than the channel in which it articulates with the femur the patella must be narrowed so it will slide backward and forward without obstruction in some cases, the width may be cut down as much as 50 per cent. Any rough cartilage on the upper

surface of the tibia is also excised Unless degenerated the semilunar cartilages are not removed Since the success of the procedure depends entirely upon removal of all mechanical irritants, Magnuson emphasizes the point that all roughness must be excised from the surface and margins of the condyles the articular surface of the patella and the upper end of the tibia

After Treatment.—Motion is begun on the fourth day with particular attention to muscle exercise Flexion is gradually increased by the insertion of laparotomy pads, one at a time, between the mattress and the posterior surface of the joint Forty five degrees of flexion is instituted during the first week Weight bearing is permitted on the eighth or tenth day provided the patient can completely extend the knee. In order to gain confidence the patient is first allowed merely to stand upon the extremity thereafter walking is gradually encouraged Crutches are not permitted though a cane may be used Magnuson states that sixty of sixty two patients with degenerative or hypertrophic arthritis of the knee were relieved of their symptoms following this procedure

Arthroplasty

Arthroplasty of the knee is not advisable unless the process is monarticular The operation is suitable principally for young individuals, particularly in the presence of incongruity of the articular surfaces and hypertrophic arthritis following fracture into the joint

Arthrodesis

With bilateral involvement fusion of the more seriously affected joint may relieve the movable joint of some of its burden of weight-bearing and thereby provide a measure of ambulation with comfort In pronounced valgus or varus deformity of the knee, with relaxation of the joint fusion is especially desirable Such a radical procedure is of course, not to be recommended unless disability is extreme

The end results are excellent the patient is able to return to his former activities without pain and, as a rule is much pleased with his improvement, although motion of the knee is permanently lost.

The technical procedure for fusion of the knee is described in detail in Chapter XV

Patellectomy

The most disabling feature of hypertrophic arthritis of the knee may be the roughening of the contiguous articular surfaces of the patella and femur A localized form of arthritis between the patella and femur alone presents a much more favorable type of joint for patellectomy than arthritis involving the entire joint, or one which is a part of a generalized hypertrophic arthritis. Such a localized form wherein the articular surfaces of the patella and femur are damaged and degenerated may follow acute or chronic trauma or osteochondritis dissecans, or may develop in a bipartate patella

Even in an extensive hypertrophic arthritis of the knee joint with an associated proliferative synovitis, a fringe of osteophytes at the edges of the cartilage or degeneration of the articular cartilage surgery is usually limited to simple excision of the patella This is quite a contrast to the procedure described above by Magnuson Young and Regan however have occasionally combined simple excision with a cheilotomy

Berkheiser observed that following excision of the patella for arthritis of the knee joint the range of motion generally increased and the quadriceps

group of muscles actually gained strength. He does not consider this procedure a specific treatment for arthritis rather it is a means of eradicating a definite mechanical impediment to function which results from changes secondary to chronic arthritis, and thereby relieving the patient from pain on active extension He defined the indications for operation as follows

1 The disease should be of several years' duration

2. Recurrence of symptoms following repeated attempts at conservative treatment.

3 The arthritis should be quiescent at the time of operation

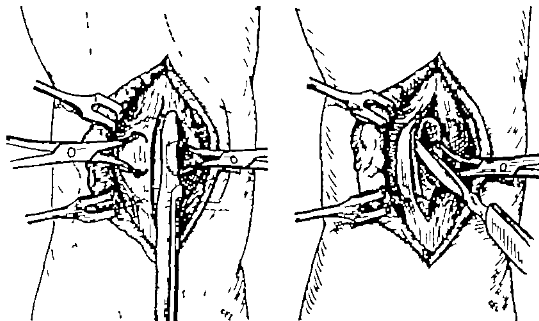


Fig. 578.—Boyd technic of patellectomy Quadriceps tendon incised longitudinally Patella divided through three-fourths of thickness by hand saw (From Boyd, H. B., and Hawkins, B. L. Surg., Gynec. & Obst. 86: 357 1948.)

Fig. 579 —Same as Fig. 578. Halves of patella removed by sharp dissection. (From Boyd, H. B., and Hawkins, B. L. Surg., Gynec. & Obst. 86: 357 1948.)

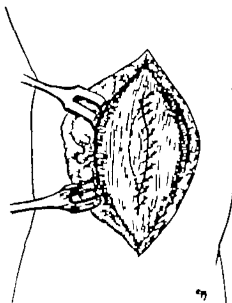


Fig. 580 —Same as Fig 578 Defect in quadriceps tendon eradicated by imbrication. (From Boyd, H. B., and Hawkins, B. L. Surg., Gynec., & Obst. 86 357 1948.)

4 Roentgenograms should show definite evidence of hypertrophic arthritis
5 The knee must extend to at least 160 degrees.
6 The mental and physical status of the patient must be such that he will cooperate in the postoperative care and be able to stand and walk

In the presence of bilateral lesions, the most severely involved joint is operated upon, the least involved being observed as a control

When patellectomy is combined with synovectomy an anteromedial incision (p 140) must be used, for fresh fractures, a transverse incision, obviously, is advantageous. Otherwise, patellectomy, through a split patellar incision is definitely superior By this technic, dissection of the soft parts is facilitated reaction postoperatively is minimum the residual defect is easily repaired and motion can be instituted in 10 to 14 days.

Technic (Boyd)—A parapatellar incision is made extending one inch proximal and distal to the borders of the patella The quadriceps and patellar tendons are incised longitudinally in the line of the incision directly over the patella The medial and lateral sides of the patella are grasped with towel clips and traction is exerted in an upward direction With an ordinary hand saw the patella is divided longitudinally through three-fourths of its thickness, thus preventing bone dust from entering the joint and eliminating the possibility of scarring the articular surface of the femur The division of the final one-fourth of the patella is completed by manual force or with a chisel The joint is then inspected for loose bodies and any small particles of bone which may inadvertently have been introduced. Thereafter the two halves of the patella are enucleated from the quadriceps mechanism by either blunt or sharp dissection This procedure usually leaves a small defect in the quadriceps mechanism this is repaired by plicating the lateral edge over the medial edge of the tendon

After Treatment.—Immobilization is maintained for four or five days by means of a Buck s extension Quadriceps exercises are begun as soon as the soreness has subsided. The ability to contract the quadriceps muscle actively without movement of the knee joint may be materially facilitated by the initiation of these exercises preoperatively Active exercises of the joint are not instituted until the wound has completely healed. Walking without the aid of support is permitted as soon as the quadriceps muscle is sufficiently strong pain subsides, and the range of motion in the joint is adequate Physical therapy will considerably shorten the period of convalescence Even in younger individuals restoration of the quadriceps mechanism to approximately normal following patellectomy may require several months. Frequently recovery is not complete until six months have elapsed

HYPERTROPHIC ARTHRITIS OF THE HIP

Coxa Malum—Coxa Magna

Hypertrophic arthritis of the hip and coxa malum or coxa magna are terms herein loosely applied to cover the same clinical entity The symptoms and residual mechanical status of the hip are essentially identical, regardless of the etiologic factor Symptoms which develop insidiously during middle age may arise from trauma, or the origin may be obscure. In some cases, the lesion may be traced to a disturbance of the upper femoral epiphysis during or prior to adolescence or to a congenital dislocation of the hip In other cases, the affection may be a part of a generalized hypertrophic arthritis.

Any condition which changes the normal anatomy to an irregular or incongruous joint, thus increasing the usual wear and tear on the joint, may give rise to a coxa malum or coxa magna deformity

Coxa malum is characterized by a diminution of the joint space and flattening or incongruity of the head of the femur As the process advances, the head of the femur enlarges and assumes a mushroom shape, the neck becomes short and broad and osteophytes form at the junction of the head and neck. Along the rim of the acetabulum osteophytes may coalesce to form an osseous hood over the outer portion of the head of the femur from ossification of the capsule. As the density of the bone increases, the head becomes interspersed with degenerative cystlike areas.

During the past ten years, we have practically limited surgery for coxa malum to the mold arthroplasty of Smith Petersen or to arthrodesis. Recognizing however that opinion will not be unanimous in this regard we present an example of each of the other types of operation for coxa malum Operative measures for hypertrophic arthritis or coxa malum of the hip may be enumerated as follows (1) cheilotomy, (2) reconstruction operation of Whitman or others, (3) reconstruction of the head (4) acetabuloplasty (5) mold arthroplasty (6 subtrochanteric osteotomy and (7) fusion Recently, obturator neurectomy has been used as an adjunct to conservative measures By reducing the amount of pain and spasm perhaps the function of the hip may be prolonged. Our series of cases is yet too small to justify our either encouraging or discouraging use of the procedure We have had no experience with the more extensive neurectomies

The majority of patients prefer an operation which will allow motion, despite the possibility of having some pain, rather than submit to arthrodesis. Mold arthroplasty provides a most satisfactory answer for this lesion and may be expected to produce a high percentage of efficient joints A complete discussion of arthroplasty will be found in Chapter XVII In selecting arthrodesis as the preferred treatment, one must be guided by the social status of the patient, the local condition within the hip and the extent of hypertrophic arthritis in other joints. For example, if the patient is a laborer and the affection is unilateral, fusion is the procedure of choice although inconvenienced by an ankylosed hip he is nevertheless enabled to work without suffering pain Subsequently disability is more or less static.

Cheilotomy

Cheilotomy was formerly employed for removal of large osteophytes which caused definite limitation of motion or impinged upon the acetabulum. Because of the marked fibrillation and degeneration of the articular surfaces, the operation proved of little value in relieving symptoms and was therefore completely abandoned. The procedure is of material historical interest, however since the mechanical principles involved are followed in more recent operations.

Technic (Murphy)—Murphy approached the joint through the lateral U incision (p 147) At the present time, the anterior iliofemoral incision is preferred. By either approach the operative technic within the joint is the same.

When the capsule is incised an osseous prolongation of the acetabulum is observed forming a hood over the head of the bone. This hood is chiseled off down to the normal margin of the acetabulum. If the head is materially

enlarged the hip is completely dislocated Extensive outgrowths of bone and cartilage or osteophytes about the head are completely removed with a chisel, and the head is reduced into the acetabulum

Reconstruction Operations

Reconstruction operations such as the Whitman procedure (p 663) which were primarily devised for ununited central fractures of the neck of the femur and are still employed for that purpose are described in Chapter X In the treatment of osteoarthritis they are seldom entirely successful

Revision or remodeling of the head of the femur has been advocated By this technic, a large portion of the head is removed leaving a small cervical head in a relatively large acetabulum

Technic.—Through an anterior iliofemoral incision, the capsule is exposed and the head of the femur dislocated from the acetabulum The mushroom shaped head is trimmed to one-half its former size as much of the articular cartilage as possible being retained The hip is then reduced and the range of passive motion, particularly flexion and abduction determined. (If removal of an excessive amount of the head and cartilage should be found necessary to secure a fair range of motion the remaining portion of the head may be excised and the Whitman reconstruction operation carried out.)

After Treatment.—With the hip in abduction a double spica cast is applied and maintained for four weeks. This is followed by after treatment similar to that employed subsequent to other reconstruction operations (p 663)

A certain number of patients obtain little relief from symptoms by this procedure. Usually the articular cartilage must be so extensively resected that the cancellous bone of the head articulates with the already degenerated articular cartilage of the acetabulum

Arthroplasty

In contrast to the procedure for reconstruction of the head of the femur arthroplasty wherein the head and acetabulum are remodeled and the joint lined by a double layer of fascia lata, prevents friction between cancellous bone and the articular cartilage Even so, with few exceptions, the results of fascial arthroplasty for this condition have been unsatisfactory Degenerative changes and partial absorption of the head frequently take place several months after the institution of weight bearing thus materially impairing function.

In our experience Vitallium cup arthroplasty, as described by Smith Petersen (p 1088) has been a more successful procedure With the exception of those engaged in hard labor this is the procedure of choice Although the range of motion may not approach normal in every instance, it is usually sufficient to afford a functional joint

Acetabuloplasty

In 1935 Smith Petersen devised a procedure known as acetabuloplasty which consisted of removal of the anterior superior wall of the acetabulum. By this technic it was intended that the impingement of the femoral neck on the acetabular margin would be removed thereby relieving pain and providing for an improvement in the range of motion



Fig. 581.—*A* Hypertrophic arthritis of hip with narrowing of joint space. Patient incapacitated by limitation of motion and pain. *B* Eight months after mold arthroplasty patient has stable hip, functional range of motion, and only mild incapacity from pain.



Fig. 582.—Smith-Petersen acetabuloplasty Insert shows rim of acetabulum inside dotted lines removed.

In our small series of cases wherein acetabuloplasty was utilized for hypertrophic arthritis of the hip the results were unsatisfactory Pain was not relieved and motion was seldom improved This technic however was a start in the right direction Smith Petersen showed that the anterior acetabulum could be excised without joint instability Further in the evolution of this technic Smith Petersen developed an anatomic approach that provided excellent exposure of the acetabulum The approach and the principle of acetabuloplasty have been subsequently enlarged upon and incorporated successfully into the technic of mold arthroplasty, thereby reconstructing both sides of the joint so that the surfaces are congruous and work smoothly in relation to one another

Subtrochanteric Osteotomy

Subtrochanteric osteotomy is designed to change the burden of weight bearing from the normal angle of the neck directly onto the head of the bone and form a new weight bearing surface between the head and acetabulum Coincidently, external rotation and adduction deformities may be corrected. When the distal end of the fragment, which includes the trochanter neck, and head, is angulated toward the midline, the rim of osteophytes along the margin of the head is displaced slightly lateral to its previous position. This in itself tends to increase motion and reduce pain from impingement of the osteophytes on the rim of the acetabulum.

McMurray has arrived at the following conclusions regarding the treatment of osteoarthritis of the hip joint That arthroplasty is theoretically an ideal operation, but produces no real benefit that arthrodesis relieves pain but increases strain on the lumbar spine and sacroiliac region and that the bifurcation operation of Lorenz or subtrochanteric osteotomy is the simplest of all, and, if performed correctly, leads to relief of pain and deformity without loss of stability or without strain upon the lumbar region

Certain requisites must be fulfilled prior to osteotomy (1) flexion deformities must be corrected and (2) sufficient motion must be present to allow adduction of the proximal fragment after osteotomy

In twenty-six patients operated upon for intractable pain associated with hypertrophic arthritis of the hip King reports that the operation successfully relieved pain in every instance. McMurray reports that results are excellent so far as pain is concerned and that more than 50 per cent of the motion is retained.

Technic (McMurray) —Through a lateral incision four to five inches in length, the trochanter and upper three inches of the shaft are exposed. The osteotomy is carried out obliquely from below upward and inward, at a point approximately 1 to 1½ inches below the vastus externus line the inner end of the lower fragment being one-half inch below the level of the head of the femur The lower fragment is then displaced medially and upward bringing the shaft of the femur just below the lower border of the acetabulum In turn, the distal end of the proximal fragment is displaced toward the midline no special effort is required as a rule to execute this maneuver as the proximal fragment tends to follow the lower fragment Exposure should be adequate to permit one to ascertain by inspection that this position is secured. The shaft of the femur is thus extracapsular and there is no danger of union between the shaft and the acetabulum Unless the position is maintained, the result will be unsatisfactory

After Treatment.—The extremity is immobilized in a plaster cast, the hip being held in the neutral position between abduction and adduction. Complete freedom of movement is not allowed for four to five months, although during the last two months of this period walking and weight bearing with crutches are permitted.

As a treatment for osteoarthritis, our experience with this procedure is limited Its lasting benefits would seem to be questionable. One of the objectionable features of the treatment prolonged immobilization in a cast may be overcome by the use of a Blount plate (Fig 715)

Arthrodesis

Fusion of the hip in osteoarthritis is indicated (1) when the lesion is confined to one hip, destruction of the joint surfaces is extensive motion is markedly limited pain is excessive, and the patient is willing to accept a stiff joint in order to secure relief from his symptoms (2) after failure to relieve symptoms by less radical surgical procedures. Fusion should not be attempted if other joints, particularly the spine or opposite hip are materially affected

There is a wide diversity of opinion as to the merit of nailing alone without intra-articular arthrodesis It is our belief that when feasible intra articular arthrodesis should be combined with nailing To combine the two at one operation without undue shock to the patient the hip should not be dislocated A considerable amount of cartilage may be removed from the acetabulum and head of the femur without dislocation.

Watson-Jones has abandoned the one-stage arthrodesis, preferring the two-stage procedure wherein an intra articular arthrodesis is first carried out and followed later by the introduction of a three flange nail. The only exception to this rule is a condition wherein the hip is practically ankylosed or one wherein ankylosis would occur eventually even though the nail were not introduced as in atrophic arthritis of the hip

Dickson and Willien noted that arthrodesing procedures for degenerative arthritis in elderly individuals were attended in general by the following disadvantages (1) the procedures were formidable and time consuming often associated with severe shock (2) they required long periods of immobilization in plaster thus presenting the serious hazard of postoperative complications in elderly individuals (3) prolonged hospitalization involved a considerable financial expenditure The operation later described by Watson-Jones obviated some of these difficulties. This was a two-stage procedure however and too formidable for elderly patients which in itself was a considerable disadvantage. Dickson pointed out that it was rather difficult to remove the cartilage from the head of the femur and from the acetabulum and at the same time obtain maximum bony contact i e by reducing the size of the femoral head and increasing the size of the acetabulum. The diminished bony contact would lead to rotary movement and instability of the joints, and perhaps interference with fusion. If intra articular arthrodesis were not performed the joint might be fixed in the deformed position at a later date requiring surgical correction In their attempt to overcome these difficulties, Dickson and Willien devised a new procedure, which is performed in one stage The hip joint is mobilized sufficiently to permit correction of any adduction or flexion deformities before the application of internal fixation To minimize shock, the hip should not be dislocated rather the cartilage on the head of the femur and that of the acetabulum is not removed, but is fishscaled or laminated Internal fixation by means of a

nail is utilized to obviate the necessity for external fixation. Finally a graft is applied to increase stability of the joint and to insure fusion.

Technic (Dickson, Willien).—The hip joint is exposed by a Smith-Petersen incision. With the special curved chisels employed for a Smith-Petersen arthroplasty, the fibrous union of the hip joint is broken up and the cartilaginous surfaces of the joint are thoroughly laminated or fishscaled. The hip joint may thus be placed in a position of 150 degrees' flexion, 180 degrees' abduction and 175 degrees' external rotation. With the hip joint in optimum position a nail five and one half or six inches long is inserted under roentgenographic control through a second small lateral incision over the trochanter. To facilitate the insertion of the nail into the sclerosed bone of the acetabulum the sclerosed portion is laminated with a chisel at the time the femoral head is freed from the acetabulum. Care should be exercised to impact the joint as the nail is being driven in. A block of bone is then removed from the anterolateral surface of the femoral neck and head and from the contiguous portion of the acetabulum margin to form a slot into which a graft is fitted to key the joint.



Fig. 583.—*A*, Obese, nervous female, aged 33, with moderately advanced arthritic changes in hip. *B*, Fifteen months after fusion. There is very little difference in preoperative clinical and roentgenographic examination of this case and that shown in Fig. 581. Choice of arthrodesis based on general rather than local considerations.

After Treatment.—The patient is allowed up on crutches after four to six weeks. No external immobilization is utilized. The amount of activity is governed by the progress of the fusion, any undue strain on the joint being avoided until fusion is complete.

At the Campbell Clinic, we arrived at the same conclusions as Dickson and Willien and have for several years been following a procedure which varies from the foregoing only in the detail of the grafting. As a rule, we have bridged the trochanter and acetabulum using a graft consisting of the outer cortex of the ilium. There are probably some definite advantages, however, to keying the joint after the manner of Dickson and Willien.

HYPERTROPHIC ARTHRITIS OF THE SPINE

As a rule, hypertrophic arthritis of the spine is associated with a generalized osteoarthritis. The entire spine, as well as the sacroiliac joint, may be involved to an equal degree Conservative measures generally suffice for this type of arthritis, fusion operations seldom being indicated.

In relatively young adults, a type of hypertrophic arthritis is often observed wherein the process is localized to one or several vertebral articulations, the remaining areas of the spine being essentially normal The roentgenogram demonstrates a typical local osteoarthritis, with narrowing of the joint spaces, incongruity of the articular surfaces, and lipping to an exaggerated extent. Although the exact etiology is unknown the lesion is probably an infectious or traumatic lesion of the disc In contrast to localized low grade infectious arthritis of the spine however destruction and erosion of the articular surfaces are not extensive and the production of new bone is not sufficient to bring about spontaneous ankylosis. Since the lesion is well localized and spontaneous fusion does not occur fusion is often advisable

HYPERTROPHIC ARTHRITIS OF THE ELBOW

Operations for hypertrophic arthritis of the elbow are seldom justified except for the removal of loose bodies which produce definite symptoms of articular impingement (p 270) (Also see baseball pitcher s elbow p 281)

LOW BACK PAIN—SCIATIC PAIN

Because of the number of possible etiologic agents, low back pain or sciatic pain frequently presents a difficult clinical problem. The cause may be indefinite and even the exact location of the pathologic process may not be readily determined In some cases, the pain may be induced by extrinsic affections of the genitourinary gastrointestinal, female reproductive, or nervous systems. The remainder are lesions which involve directly or indirectly the vertebrae or vertebral articulations. Congenital anomalies (see spondylolisthesis) traumatic, postural, or static affections neoplasms, infection or degenerative diseases may be responsible singly or in combination For this reason, the treatment of symptoms referable to the low back region will be considered together

An exhaustive differential diagnosis is imperative This necessitates a comprehensive familiarity with these affections. By a careful evaluation of the history and physical findings, including those of a thorough neurologic examination, extrinsic and intrinsic lesions may be differentiated The common symptoms and findings observed in the latter are low back pain, which may or may not be definitely localized by pressure, faulty posture as a result of spasticity and rigidity of the spinal muscles, and radiating or referred pains, generally of sciatic distribution One or all of these symptoms may be present.

According to Steindler local tenderness, faulty posture and radiating pain may not only be induced by deep-seated spinal lesions or by direct pressure on the nerve roots in the intervertebral foramina, but also by superficial lesions of the myofascial and aponeurotic structures. The radiating pains associated with peripheral lesions which involve the posterior roots of the spinal nerves are produced as a reflex symptom. To establish a causal

relation between the local superficial pain and radiation, the following test is carried out in patients with a definite, superficial, tender point elicited by palpation and with pain referred to this point by leg signs Five to ten cubic centimeters of 1 per cent procain hydrochloride solution are injected into the point of acute tenderness. The reflex relation between the localized lesion and the radiation may be assumed if contact with the needle aggravates the local pain and exaggerates radiation if the procain hydrochloride suppresses the local tenderness and radiation and if the positive leg signs disappear



Fig 534—Localized osteoarthritis of spine relief of pain following Albee bone graft.

The examination should be carried out meticulously with special attention to neurologic signs. Roentgenograms are particularly valuable, but expert interpretation is required to determine whether the evidence presented explains the patient s symptoms. In addition to the ordinary roentgenograms in two

planes, which may not show sufficient abnormality of the bony structures to account for the symptoms, oblique views of the articular facets are usually made. When intraspinal lesions, as protruding intervertebral disc, or spinal cord tumor are suspected, roentgenograms made after the injection of Pantopaque may reveal the location of the lesion and substantiate the diagnosis.



Fig. 585.—Lumbosacral fusion with curved full thickness cortical graft for narrowed lumbosacral joint with arthritic changes.

CONSERVATIVE TREATMENT

In the majority of cases, low back pain responds to conservative measures, as braces, physical therapy Bradford frame with traction, correction of posture, or exercises. This is particularly true when arthritis, of either traumatic, degenerative, or infectious origin, or a superficial lesion of the myofascial structures is the causative factor Conservative treatment, therefore, should be given a thorough trial before radical procedures are undertaken The site and type of the disturbance, should be definitely determined. This may be difficult if root pains of a sciatic distribution predominate and the clinical and roentgenographic findings are not conclusive.

Complete Rest on a Hard Bed or Bradford Frame—For many years, it *has been our custom to keep the patient in a supine position with traction on* both legs. This has proved satisfactory in the vast majority of cases. Williams and others recommend placing the patient in Fowler s position with the spine,

s, and knees flexed the purpose being to relax the muscles, relieve tension on sciatic nerve and open the posterior portion of the intervertebral space We e found this advisable for patients who do not tolerate the horizontal posi n particularly those with disc lesions. The period of bed rest varies from) to four weeks, or until the muscle spasm and pain have been relieved vided operative treatment is not meanwhile deemed advisable

Physical Therapy and Exercises—Physical therapy in the form of dry t or moist packs with massage is begun immediately Carefully guarded k and leg exercises are instituted as soon as the acute irritability of the k and sciatic nerve has subsided Graduated reconditioning exercises of the k and thigh should be continued for several months after the patient reнes walking

Support.—As soon as the patient is permited out of bed a back brace ig 36) should be applied to be removed gradually as the symptoms permit.

If after three weeks of complete bed rest in the hospital, combined with other measures described above the patient still exhibits muscle spasm atic scoliosis and sciatic pain with or without other symptoms and findings back irritability one may assume that conservative treatment has been of le avail Often however patients having their first attack and those in the er age group may wisely be treated by conservative methods for an indelte time. This is also true if compensation or litigation is pending

SURGICAL TREATMENT

With the exception of such lesions as tuberculosis and spondylolisthesis, erein surgery is more or less mandatory operative measures are indicated less than 10 per cent of patients observed for complaints relative to the low k area The majority of the 10 per cent will have disc lesions. To apply a de variety of operations to the remainder is neither necessary nor practicable. e rise and fall in popularity of various procedures for this group over a riod of twenty years is evidence enough that the results were not satisfactory ıch of the confusion has been cleared since the prominent role of disc lesions s recognized We have abandoned muscle stripping operations, tenotomies, d fasciotomies. Arthrodesis of the sacroiliac joint is practically a thing of the st. Other measures, such as manipulation, are not a part of our treatment. ıde from minor procedures (p 877) we limit surgery for low back pain and iatic pain to three operations (1) arthrodesis (p 967) (2) removal of a otruded disc (p 870) and (3) a combination of arthrodesis and removal of protruded disc

Arthrodesis alone is employed in localized arthritic lesions of traumatic, deнerative or infectious origin or for unstable vertebrae of congenital origin uch have not responded to conservative measures. In the majority of cases, e use iliac grafts and a combination of the Hibbs and Albee operations.

The indications for removal of a disc, or removal of a disc with arthrodesis quire more detail. Lenhard reports good results in 67 5 per cent of patients o had a ruptured intervertebral disc removed without spinal fusion. Barr om a study of 102 patients with spine fusion and 132 without spine fusion served that those who had a fusion had moderately but definitely better end sults than those who had no fusion He concludes that if a technic of fusion n be developed which would not unduly increase the operative risk, nor olong convalescence fusion would appear the logical course in practically all ses Love speaking from an experience of 1 217 patients operated upon for

protruded intervertebral disc feels that a bone graft should be combined with removal of the disc only if the indications are definite, and that routine bone grafting is not justified He does not describe what these ' definite' indications should be

Such widely divergent views represent a cross-section of the contemporary literature on this subject. Perhaps the following detailed section will not clarify this situation. We have, however, set forth our opinions as definitively as present knowledge permits. Realizing that there are some discrepancies between the attitude of orthopedic surgeons and neurosurgeons, we are presenting the subject from both the orthopedic and neurosurgical viewpoints.

RUPTURE OF LUMBAR DISCS

In 1934 Mixter and Barr first described the symptom complex the operative findings and pathologic data upon which the present concept of the ruptured intervertebral disc syndrome is based Prior to that time, this lesion was an unknown clinical entity in the brief period of thirteen years, it has come to be recognized as the most common explanation of low back disability The acceptance of this concept by the majority of the medical profession is supported by sound operative evidence and pathologic investigation

Approximately 20 per cent of the patients between the ages of twenty and fifty years who present themselves with a complaint only of low back pain receive a diagnosis of probable injury of the fourth or fifth intervertebral disc. Of those who complain of low back pain combined with true sciatic radiation 80 per cent are considered to have disc injuries with probable protrusion A study of our cases and a compilation of the reports of others indicate that of patients with proved herniated discs 80 per cent were between the ages of twenty and fifty In 95 per cent, the location of the herniation was in the fourth or fifth lumbar interspace, approximately 10 per cent more being in the fifth rather than in the fourth In 15 per cent protrusions were found in both the fourth and fifth interspaces. We now routinely explore both spaces.

Herniation of a disc is produced by a single mechanical stress, in a normal or unstable lumbar spine, of sufficient force to produce a rupture with protrusion of the intervertebral disc, or from multiple minor stresses on an unstable joint, with repeated trauma to the disc of sufficient severity to produce degenerative changes in the disc and eventual rupture There is some question of this theory however as the sole cause of rupture of an intervertebral disc. It is recognized that in old age, the discs undergo gradual desiccation and degeneration In generalized atrophic spondylitis, there is a compression of the central portions of the vertebral bodies with an accompanying widening of the disc spaces, producing the fish type of interval between vertebrae. In this type of spine and in others as well a partial herniation of the disc frequently takes place in the bodies of the vertebrae giving rise to the conditon known as Schmorl's nodules. The prevalence of the lesion in younger individuals and the location of the herniation in the true ruptured disc is strongly contradictory evidence against such a theory Until further evidence is produced as to the theory of primary degeneration of the disc, therefore we must assume that the lesion is traumatic in origin.

The herniation occurs at the weakest point in the annulus, its posterior portion adjacent to the spinal canal usually along the lateral border Recent observations have shown that the annulus has a sensory nerve supply and if injured or abnormally compressed it can produce symptoms of low back pain

without impingement upon the spinal nerve roots. This probably accounts for the atypical clinical picture presented by many patients with minor herniation or with central ruptures without any of the ordinary organic neurologic signs. The spinal nerve roots lie loosely in the subarachnoid space unless they are adherent to the protruding disc or are caught near their entrance to the vertebral canals, considerable displacement is permitted without symptoms

The typical sciatic syndrome is produced by irritation of the spinal nerve roots, usually the root below the interspace wherein the herniation takes place The symptoms of root irritation are caused by direct pressure by stretching or by adhesions between the nerve root and the presenting portion of the disc. When the elasticity of the disc is impaired by the loss of the nucleus pulposus the remaining portion or annulus undergoes progressive degenerative changes with narrowing of the intervertebral space The narrowing of the intervertebral space is accompanied by a settling of the vertebral body in many cases to one-fourth inch Increased mechanical stress is thus imposed upon the articular facets. As a consequence of these factors, traumatic arthritis develops in the articular facets and between the vertebral bodies.

Following destruction of the fifth disc and loss of motion in this articulation, the fourth disc is placed under increased mechanical stress and eventually may also rupture

In 90 per cent of the cases a diagnosis of ruptured disc may be made from a careful study of the history physical findings and roentgenologic evidence (see p 867) If the diagnosis is doubtful a period of conservative treatment and observation will often clarify the question

The roentgenologic criteria are less widely understood Immediately following and for some time after the rupture the roentgenograms are usually negative. Changes which may be visualized in the roentgenogram take place slowly narrowing of the affected interspace will be apparent sooner or later usually by the end of a year The condensation and proliferative changes in the bone which are characteristic of traumatic arthritis are demonstrable, as a rule, only after several years. By consecutive roentgenograms, we have been able to observe this process of gradual narrowing from its incipiency to the final stage. In the majority of patients who present themselves for treatment in an orthopedic clinic sufficient changes are present to warrant the diagnosis of a disc injury

Those patients who give a long history of back disability and pain which finally subside only to recur after many years, constitute an interesting and instructive group Here, the roentgenogram will show obliteration of the fifth interspace with advanced arthritic changes, while the fourth interspace appears normal At operation some scarring and adhesions, though no protrusion of the fifth disc is found. On exploration of the fourth interspace a fresh herniation is discovered, being the source of the recurrent symptoms. This picture justifies the following conclusions

1 Symptoms from ruptured discs may subside spontaneously and permanently

2 Ruptures of the fourth and fifth discs may produce essentially the same symptom complex.

3 Destruction of a disc with the development of an associated traumatic arthritis does not of itself cause continuous disability

A wide divergence of opinion still prevails as to the proper treatment of patients with a traumatic lesion of the intervertebral disc. This divergence of

opinion arises from many factors inherent in the clinical manifestations of this entity and the mechanics of the lesion itself. The interpretation of the results of the various forms of treatment depends primarily upon the relief obtained Conservative treatment may afford only temporary relief, leading to a false estimate of its value However the effects of any form of treatment may be influenced by psychologic or financial considerations. These factors may be the sole basis for the initial complaint or in the presence of a true organic lesion for a prolongation of their disability following adequate treatment In industrial cases, the physical findings and psychologic background of the patient should be carefully evaluated before surgical treatment is advised

The fact that, prior to 1934 millions of patients with disc injuries must have partially or completely recovered without the aid of surgical intervention leads one to conclude that nature s efforts, aided by time and various conservative measures, provide adequate relief in many of the less severe cases. Such a fortunate resolution of the problem however is by no means universal We can all recall patients who suffered and were disabled for years with low back pain with or without sciatica, who failed to respond to every conservative treatment. For such individuals, present-day surgery offers definite relief For many others in the initial period of the disability it offers a quick relief of pain, a material shortening of the period of disability and a much more definite protection against subsequent attacks.

The final decision as to which patients should be treated conservatively and which should be operated upon probably can never be made as, unquestionably some disc protrusions are progressive some remain stationary and some are regressive. The status of each patient may alter from time to time Those with early or doubtful disc lesions should be kept under observation until their status is definitely determined before operation is advised

All things considered both neurologic and orthopedic surgeons agree that the majority of patients who exhibit the syndrome of a ruptured disc may be relieved temporarily or permanently by nonsurgical measures. In 1941 Kuhns reported a series of one thousand consecutive patients with low back pain with or without sciatic pain who were treated by conservative means. Seventy-seven per cent were relieved of their pain. In 50 per cent of these however the pain had been present for only two weeks or less. In such cases, the problem is different from that presented by the patient with the usual disc syndrome. Many of those whose symptoms were of longer duration would be regarded by others as having chronic back disability wherein disc injuries are considered the predominant cause of the complaint. Our patients who have had a diagnosis of provable disc injury have been treated as follows

1. Immediate surgical exploration	10%
2. Surgical exploration after conservative treatment	20%
3. Treated, or advised to be treated conservatively	70%

It is presumed that a number of those for whom conservative treatment was advised or who were treated conservatively sought surgical relief elsewhere.

Conservative Treatment.—As a practical plan we advise conservative treatment (see p 860) on the following groups of patients

1 Those having their first attack whether mild or severe
2. Those who have recurrent mild attacks at infrequent intervals
3 Those over fifty years

4 Those who present some doubt as to the diagnosis or the type of operation to be employed

5 Those who have recurrences of pain after removal of a disc a further period of treatment and observation being undertaken to determine the probable cause of the pain

If conservative treatment fails to relieve symptoms the decision as to the type of further treatment should be based upon a careful analysis of the case as a whole This should include the history as to the duration severity and frequency of previous attacks the neurologic findings, roentgenologic data and the patient s response to conservative treatment The practical solution particularly for patients in the young or middle age groups, is surgical removal of the disc either with or without a lumbosacral fusion Patients in their first attacks, or in the older age group may wisely be continued on conservative treatment If the attacks recur after temporary relief from conservative treatment are more severe and frequent enough to be disabling continued treatment by conservative means is usually inadvisable

Surgical Treatment.— An analysis of the results obtained by conservative treatment in patients who have had a diagnosis of ruptured discs since 1934 and of the thousands who unquestionably had unrecognized disc lesions prior to that time proves that the diagnosis of a ruptured disc is not necessarily an indication for its removal The symptoms and the patient s response to conservative treatment are the deciding factors

Formerly lumbosacral fusion was performed without the removal of probable protruding discs, with relief of both back and sciatic pain in a high percentage of cases. From this fact it is evident that stabilization of the lumbar spine is a definite adjunct to the operative treatment of these patients. In the light of our present knowledge concerning discs, however one is no longer justified in performing a fusion without eliminating the probability of an accompanying disc by exploration of both the fourth and fifth interspaces. Unless both spaces are explored it is impossible to determine conclusively whether the protrusion is in the fourth or fifth space or in both. Failure to remove such protruding discs before fusion may not only result in continued disability but may render subsequent surgical exploration far more difficult

The indications for surgical treatment are as follows

1 Patients with intolerable sciatic and back pain of short duration who are unrelieved by a reasonable period of conservative treatment. Although some of these patients might eventually be relieved by further conservative measures the majority will probably be saved a long period of suffering and disability by surgical intervention

2. Patients who give history of repeated disabling attacks over a long period of time, which have been only temporarily or incompletely relieved by conservative methods. These patients usually present in addition positive neurologic findings of nerve root damage and roentgenographic evidence of a severe disc protrusion

3 Patients who experience a prolonged initial attack or a severe recurrent attack of over three months duration Such patients will usually have recurrences, even though eventually relieved by nonoperative methods.

4 Patients with signs of impending serious neurologic damage These fortunately few in number are usually found to have some other type of lesion such as a spinal cord or sacral tumor

There is still no agreement among orthopedic surgeons or between orthopedic and neurologic surgeons as to which patients should have the disc removed

alone, or should have the disc removed followed by lumbosacral fusion necessity for a decision regarding this issue is urgent If lumbosacral increases the number of satisfactory results, or contributes to the perm of the results, it should be utilized when indicated If fusion does n tribute materially to the patients recovery it should be omitted regard the type of fusion performed the magnitude of the surgical procedure materially increased

In general, orthopedic surgeons agree that if surgery is indicate disc should be removed even though they consider the protrusion of t to be only partially responsible for the disability A persisting inst of the lumbar spine may be the primary factor in the rupture of the di mechanical defect together with subsequent changes incident to the loss support of the disc may cause continued disability following a removal disc For this reason we advise the combined operation for those cases t in the categories listed below This opinion is not generally shared by neu surgeons Certainly in the past they have advised few fusions in con with their disc operations. Neurologic surgeons probably see more early yet the fundamental problem is essentially the same. In many of the clinics where neurologic and orthopedic surgeons work in cooperation up problem an increasing number of fusions are being performed.

A prolonged follow up study on a large series of cases will be nee before sound conclusions can be formulated regarding the advisability of combined with excision of a ruptured disc Sufficient time has not elaps such a study From present experience we believe that fusions should b formed in conjunction with disc removal in the presence of the followin ings

1 Instability of the lumbar spine associated with development normalities

2. Increased mobility of the fourth or fifth lumbar vertebra, may be demonstrated during the operative procedure

3 In young individuals, narrowing of the intervertebral space localized arthritic changes

4 Recurrence of symptoms after relief by conservative treatme

Theoretically the principle of lumbosacral fusion might be exten other cases for the following purposes

1 To minimize the disability from arthritic changes which even develop after most disc injuries

2. To prevent recurrent protrusion of the disc in the same inte or the protrusion of another disc in an adjacent interspace

After Treatment.—It is the opinion of most orthopedic surgeons th protrusion of the disc is only partially responsible for the initial back dis and that certain physiologic abnormalities persist in the soft tissues and structures of the back after removal of the disc. For this reason the p erative care is an important element in the patient s eventual recover surgeon s responsibility does not cease with the closure of the wound. portive treatment consisting of the same measures employed in conser management is carried out this includes an adequate period of bed rest, a for the lumbar spine and a carefully supervised period of reconditionin ercises.

The average period of disability following disc removal alone or combined with lumbosacral fusion may be stated as follows

Removal of the disc alone

Bed rest	A minimum of two weeks
Time from work:	Clerical, one month
	Labor three months

Removal of the disc combined with lumbosacral fusion

Bed rest	A minimum of four weeks
Time from work	Clerical, three months
	Labor, six months

It should be understood that although the majority of patients may be relieved of their symptoms and returned to their usual occupations, the spine is never again entirely normal either without surgery or following removal of a protruding disc, with or without lumbosacral fusion

RUPTURE OF LUMBAR DISCS

FRANCIS MURPHEY M.D

The incidence of rupture of the fourth and fifth lumbar discs with herniation of the nucleus pulposus is higher than that of rupture of all the other discs combined Such lesions usually cause low back pain followed by pain radiating to the hip and down the lateral or posterior aspect of the thigh to the calf or heel The pain is often associated with numbness and weakness in the leg and may be aggravated by coughing sneezing, bending or lifting Occasionally the patient complains of pain in the groin and rarely of sphincter disturbances The pain may begin insidiously without definite cause or the patient may give a history of injury or strain to the back accompanied by a sudden onset of symptoms. The majority report recurrent episodes of pain related or unrelated to physical effort

As a rule examination shows muscle spasm in the back with flattening of the lumbar curve and a scoliosis with the curve away from the lesion, this however may be reversed Motion of the lumbar spine is usually limited and tenderness may be elicited over the lower lumbar spine or sacroiliac joints. The Lasègue sign is practically always positive if not, the presence of a ruptured disc is highly questionable Pain in the affected hip or leg on straight leg raising of the normal extremity is almost pathognomonic of a ruptured disc.

Rupture of the fourth disc is frequently accompanied by hypesthesia in the area of the fifth lumbar dermatome, with little or no diminution of the ankle jerk. If the fifth disc is ruptured, there is usually hypesthesia in the area supplied by the first sacral dermatome, and a pronounced reduction or absence of the ankle jerk Occasionally one finds weakness, atrophy and even paralysis in the affected leg The degree and extent of the neurologic deficit depend upon the amount of pressure upon or damage to the nerve root and the number of nerve roots involved It is not always possible therefore, to localize the lesion except to the fourth and fifth interspaces, even though one is certain of a ruptured disc

Roentgenograms may show straightening of the lumbar curve and a scoliosis. Narrowing of the disc and hypertrophic changes of the adjacent vertebrae may be demonstrated though this is of no real localizing value Roentgenograms are most helpful in ruling out other lesions of the spine, pelvis, and adjacent structures. Studies of the spinal fluid may reveal an increase in

around the point of the needle and the oil is withdrawn If all of the oil is not removed, the patient may have some coccygodynia for a time. Because of the danger of infection it is most unwise to reinject any of the spinal fluid removed with the Pantopaque The needle is then removed and the patient returned to his room Following this procedure the patient may have a little fever and headache for two or three days. To minimize the possibility of a headache he is kept in the supine position for forty-eight hours Sulfadiazine is administered for twenty four hours.

Removal of Lumbar Disc

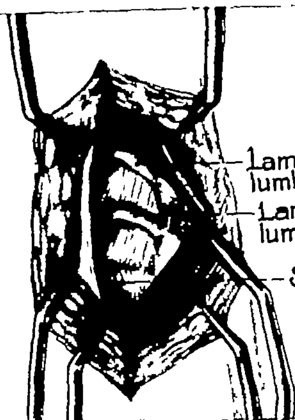
The indications for operation for a ruptured intervertebral disc in the lumbar region vary in different patients. It is well known that most patients with such lesions will recover with bed rest, leg traction, physical therapy, and some types of back support, or in fact without any treatment If conservative treatment is not effective, and if after two to three months, the pain is sufficiently severe to incapacitate the patient, operation is indicated. The symptoms and signs should warrant a clear-cut diagnosis or myelographic evidence should be unmistakable.

Operations have been performed with the patient prone, sitting, and on the side We prefer the prone position with the table broken to flatten the lumbar curve and open the intervertebral spaces

A general spinal or local anesthetic may be used. We have employed local anesthesia in approximately two thousand cases without a fatality and with generally satisfactory results. Aside from the fact that the postoperative reaction is less and respiratory complications almost unknown one is usually able to have the patient identify the involved nerve root upon its compression. On the other hand, the patient always experiences pain for a few seconds incident to the injection of the involved root Rarely is it necessary to change to general anesthesia. Two per cent procaine is injected into and beneath the skin along the line of the proposed incision. One per cent procaine is then injected into the paravertebral muscles down to the sacrum and lamina of the fourth and fifth lumbar vertebrae on the side of the lesion By 'feeling' with the needle as the procaine is injected the exact location of the various interspaces is determined and the incision is placed accordingly

Technic.—The outline of the incision is scratched on the skin before the patient is draped. This is essential because of the general tendency to place the incision too high A midline incision three or four inches long from the spine of the fourth lumbar vertebra to the first sacral spine is adequate to allow the exploration of the fourth and fifth discs. The supraspinous ligament is incised from the fourth lumbar to the first sacral spinous process. By subperiosteal dissection, the muscles are then stripped from the spines and laminae of these vertebrae on the side of the lesion Unless the herniation is bilateral, exposure on both sides is unnecessary An assistant then retracts the paravertebral muscles, exposing one interspace at a time That one may make no mistake as to the interspaces to be explored it is imperative at this point that the position of the sacrum be verified by palpation and visualization. Hemostasis must be complete The laminae and ligamenta flava are denuded with a curette. Pressure on one of the exposed ligaments may reproduce the patient's old pain, thus indicating the site of the involved disc Both the fourth and fifth discs should always be explored

Frequently the lumbosacral interspace is large enough to permit exposure and removal of a herniated nucleus without removal of any bone. If not, a small



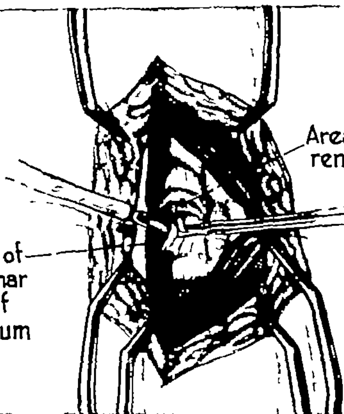
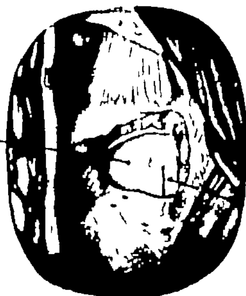
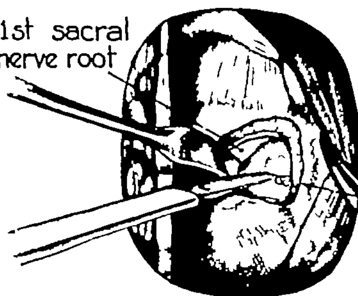


Fig. 55.—Technic of removal of lumbar disc. Exposure of interlaminar space between fourth and fifth lumbar vertebrae, and between fifth lumbar vertebra and sacrum.

Fig. 56.—Ligamentum flavum grasped by a clamp and incised at point of its fusion with the interspinous ligament. If the space is small, the inferior edge of lamina of fifth lumbar is removed.





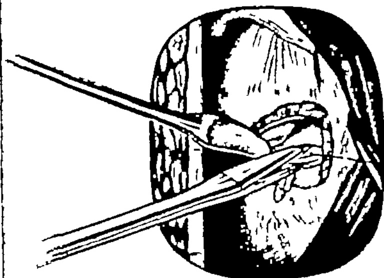


Fig. 589.—Exposure of dura and nerve root.

Fig. 590.—Nerve root dissected free and retracted medially. Capsule of posterior longitudinal ligament is incised cruciately.

Fig. 591.—Loose fragments of fibrocartilage removed with a pituitary forceps.

portion of the *inferior margin of the fifth lamina is removed*. The ligamentum flavum is grasped with a Kocher clamp and with a bayonet pointed knife is incised at the point of its fusion with the interspinous ligament. The flap of the ligament is then turned outward. All of the interlaminal portion is either removed or sutured to the paravertebral muscles and retracted out of the way. The dura is next retracted medially and the nerve root gently palpated with a blunt dissector. If compressed by a herniated disc the nerve root will be extremely sensitive and the patient will identify the pain as being of the type previously experienced. The nerve root is then injected with one per cent procaine dissected from the capsule of the herniated nucleus and retracted medially by a Love root retractor or a blunt dissector thus exposing the disc. Bleeding from the epidural veins, which usually begins at this stage of the operation is controlled by pledgets of cotton packed up and down within the spinal canal a black silk thread having first been attached to the pledgets for identification. The nucleus may be covered by a layer of posterior longitudinal ligament or may have ruptured through this structure. In the latter event the loose fragments may be lifted out by the suction or pituitary forceps. If still intact the capsule is incised crucially and the loose fragments removed. At this point one must decide whether to remove the remainder of the nucleus. We agree with *Bradford and Spurling that if the opening in the annulus is small it should* not be enlarged for removal of the remainder of the nucleus, even though recurrence is more likely if the entire nucleus is not removed. Furthermore postoperative back pain is less likely if the remainder of the nucleus is not disturbed. If the rent in the annulus is large the residual nucleus should be removed. One must remember that the anterior portion of the annulus is adjacent to the aorta vena cava or iliac arteries and one of these structures may be injured if one proceeds too deeply. This is by no means impossible and in fact is known to have happened. One should therefore insert a probe into the space and measure the distance to the anterior annulus. The remainder of the nucleus is withdrawn with a curette and pituitary rongeurs, with care not to exceed this distance. The cotton pledgets are next removed any bleeding may thereafter be controlled by Gel foam dipped in thrombin. The wound is thoroughly irrigated with saline prior to closure.

After Treatment (See p 866.)

RUPTURE OF CERVICAL DISCS

Within recent years, rupture of one of the lower cervical discs, with lateral herniation of the nucleus pulposus nerve root compression and consequent radicular signs and symptoms has proved to be a fairly common lesion. It has been estimated that approximately 10 per cent of all disc lesions develop in the cervical spine. In proportion however the number which requires surgical removal is much smaller than the number of those in the lumbar region. Medially placed herniations are much less common and may produce pressure on the spinal cord causing signs and symptoms of cord tumors lateral sclerosis *multiple sclerosis, and amyotrophic lateral sclerosis. Only laterally* placed herniations will be considered in this section.

The first symptom is usually pain and a stiffness in the neck. This condition is similar to the ordinary cricks in the neck which in most cases, are the result of actual disc injury either mild or severe. These symptoms may disappear and recur at intervals followed after a period of days, months or years, by pain in the shoulder over the anterior chest wall along the medial border of the scapula and down the arm and frequently accompanied by

numbness in one or more fingers. The pain may be so violent that the patient thinks he has suffered a heart attack or it may be so mild as to be merely annoying Movements of the neck, coughing sneezing or straining may aggravate the symptoms while supporting the arm or sleeping with it behind the head may give relief Weakness of the arm and the hand vasomotor changes, and in late stages, muscle atrophy and fasciculations may be observed

Examination usually shows severe muscle spasm on the affected side of the neck limitation of motion of the neck, and tenderness over the brachial plexus and the scalenus anticus muscle Of considerable importance is the elicitation of point tenderness over the *affected nerve root at its emergence from the spinal* canal Spurling and Scoville call attention to a neck compression test wherein pressure is exerted in the top of the head the test is regarded as positive if the pain is intensified and radiation to the shoulder or arm is reproduced. In performing this test, one should use the utmost caution. Occasionally one finds *spasm in the trapezius which causes elevation of the shoulder* If the disc between the fifth and sixth cervical vertebrae is ruptured the sixth cervical nerve root is compressed Numbness and hypesthesia may be present in the thumb index finger and on the lateral aspect of the forearm, also the biceps and deltoid muscles may be weak and the biceps reflex may be diminished Rupture of the sixth disc and compression of the seventh cervical nerve root may be accompanied by hypesthesia of the index and middle fingers weakness of flexion of the index finger and reduction or absence of the triceps reflex. Strangely ruptures of the disc between the fifth and sixth, and sixth and seventh cervical vertebrae may cause hypesthesia in the area supplied by the ulnar nerve, as well as weakness and atrophy of the muscles in the hand supplied by this nerve. Such findings, therefore, may have no localizing significance

Roentgenographic examination may show loss or reversal of the normal cervical lordosis, either complete or segmental, but usually with the apex of the reversed curve at the level of the lesion narrowing of the intervertebral space a calcification in the posterior longitudinal ligament which projects into the intervertebral foramen and defects in the myelogram. While none of the first *four of these roentgenographic findings is diagnostic, they are highly significant* when correlated with the clinical evidence If the cervical curve is normal the diagnosis must be considered doubtful Spinal puncture findings are generally identical to those observed in rupture of the lumbar disc.

The symptoms of a ruptured cervical disc may closely resemble the pain of coronary thrombosis and other types of cardiac pain The distinction depends upon whether or not the pain is reproduced by pressure on the roots of the brachial plexus, as well as upon the physical and roentgenographic changes described above, and the exclusion by proper diagnostic means of the presence of coronary disease It should be emphasized, however that precordial pain on effort, which is relieved by nitroglycerin is no longer always a definite indication of angina pectoris

It is likely that, in the majority of cases, the *scalenus anticus syndrome* is caused by a ruptured cervical disc. Further this syndrome is probably never a primary entity but is induced by some irritative lesion in the neck or shoulder girdle. It has also been thought that symptoms of this type could be produced by cervical ribs, though these give rise to numbness, weakness, atrophy and vasomotor changes, rather than to real pain. Destructive lesions of the cervical spine, and tumors of the spinal cord or of the superior sulcus of the lung should also be considered as possibilities in the differential diagnosis of a ruptured disc

Of particular importance is the relation of arthritis in the cervical spine to ruptured cervical discs. For years, some of the roentgenologic findings mentioned above have been regarded by roentgenologists as denoting hypertrophic arthritis. Regardless of how these changes are described or what they may be called, it is probable that in the majority of cases, they result from rupture or degeneration of the disc, and therefore constitute a traumatic arthritis. This opinion is based upon fairly conclusive evidence Keyes and Compère have proved experimentally that *injury to the intervertebral disc is* followed by spur formation around the edges of the adjacent vertebrae Further the two divisions of the spine which are subject to the greatest stress, namely the lower cervical and lumbar regions, exhibit far more localized spur formation than other areas. These two regions are likewise the sites of the vast majority of ruptured discs. The development of spurs on the vertebrae adjacent to ruptured discs in the cervical and lumbar regions, both before and after operation, is a common observation



Fig 512.—Pantopaque myelograms. *A* Large filling defect from rupture of intervertebral disc between sixth and seventh cervical vertebrae. *B* Small, filling defects on opposite sides of cervical spine. Ruptured disc between sixth and seventh cervical caused symptoms.

The pain in the neck, shoulder and precordium arises from injury to and bulging of the annulus fibrosus. The arm pain is caused by pressure of the herniated nucleus on the nerve root. It is unlikely that narrowing of the disc alone will reduce the diameter of the intervertebral foramen sufficiently to cause radicular symptoms, but in combination with osteophyte or spur formation may produce nerve root pressure

In most cases, a diagnosis of a ruptured cervical disc may be made from the clinical findings. Myelography with *Pantopaque* is usually quite accurate, however and should be used if the diagnosis is doubtful or if there is a probability that some other type of intraspinal lesion might be present Pain should be sufficiently severe to warrant operation if a herniated nucleus is found.

Myelography

For myelography of the cervical spine the injection is performed as for the lumbar spine (p 868), 6 c.c of Pantopaque are used. The patient's head is placed toward that end of the table which can be tilted lowest, and the head and body are supported by a shoulder rest. The patient's neck is hyperextended as much as possible, and the chin supported in this position by a sand bag and held there until sufficient oil has shifted into the cervical canal. The table is then tilted downward slowly until the oil has run into the cervical region. Extreme care should be taken at this point to prevent the oil from entering the cranial cavity. After a sufficient amount of oil has spilled into

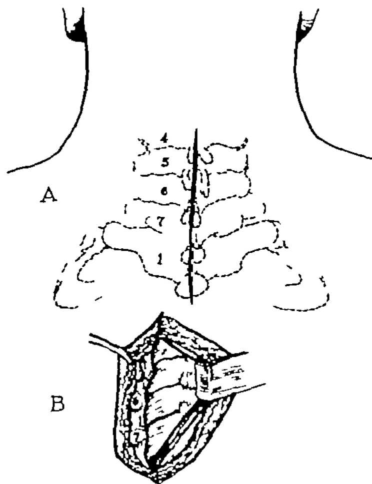


Fig. 591.—Technic of removal of cervical disc between C5 and C6. A, Midline incision extending from spinous process of fourth cervical vertebra to spinous process of first thoracic vertebra. B, Paravertebral muscles dissected from lamina and retracted laterally

the cervical region, the table is leveled since there is no longer any danger that the oil may run into the head, the sandbag is removed from beneath the chin. A roentgenoscopic examination is next made in the frontal position while the position of the table is changed to bring the oil into the various levels of the neck. Spot films are made at each level. The films are then developed and studied that one may be sure satisfactory exposures have been made

After the examination is completed, the position of the patient is reversed on the table so the feet will be at the end which descends the lowest. The table is tilted to the upright position the patient being instructed to cough and to turn from side to side meanwhile, that as much of the oil as possible may be

dislodged from the nerve root sheaths. The oil is then removed as in my elographs for lumbar discs. Usually some of the oil remains trapped in the nerve root sheaths and, in this event, may require removal later

Removal of Cervical Disc

As is true of patients with a ruptured lumbar disc the majority of those with a ruptured cervical disc recover without specific treatment Frequently symptoms are relieved by head traction heat and massage If however radicular pain continues to be incapacitating or if a marked neurologic deficit appears, operation is usually indicated If considerable spur formation is present

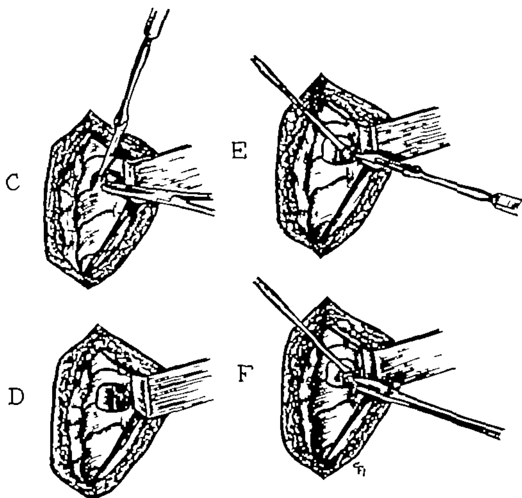


Fig. 594 Fig. 595.

Fig. 594.—Same as Fig 592. *C* With small pointed rongeurs, inferior portion of upper lamina (one-fourth by three-eighths inch wide) is removed. Ligamentum flavum dissected out. *D* Similar amount of upper edge of lower lamina and medial edge of facet removed by small sphenoid punch. Defect is now approximately one-half by one-half inch, exposing compressed nerve root and lateral edge of dura.

Fig. 595.—Same as Fig. 593 *E* Nerve root separated from nucleus and retracted upward, exposing herniated disc. *F* Longitudinal ligament incised and loose fragment of nucleus removed.

in the intervertebral foramen, as shown by oblique roentgenograms, one is less likely to obtain a good result from the operation than when no spur formation is present and the herniated nucleus is soft Because of the possibility of damage to the spinal cord, operations for such lesions are fraught with more dangers than similar operations in the lumbar region and for this reason should be undertaken with more concern

The patient is placed in the prone position with the face in a comfortably *fitting cerebellar head rest, and the neck is flexed to obliterate the cervical curve* so far as possible. The upright position which has been recently popularized, makes the operation easier by reducing venous bleeding but is exceedingly dangerous, first, because of the possibility of an air embolus to the brain and, second because of the possibility of cerebral thrombosis, or cerebral anoxia from a sudden drop in blood pressure. The use of the upright position with or without general anesthesia is never justified All serious complications thus far reported from removal of cervical discs, other than infections, have been the result of its use

Local anesthesia is by far safer and more satisfactory for this procedure than any other type (p 870) It has the double advantage of allowing the patient to identify the involved nerve root on palpation and of forcing the surgeon to be extremely gentle in the manipulation of the nerve root and spinal cord. Its only disadvantage is the momentary pain experienced by the patient when the nerve root is palpated and injected with one per cent procaine hydrochloride

Technic.—A midline incision four inches long is made with its center over the interspace to be explored The ligamentum nuchae is divided longitudinally and the tips of the spinous processes above and below the designated interspace are exposed. One s position is reasonably well assured by palpation of the last bifid spine which is usually the fifth cervical This, however should be verified preoperatively by a roentgenogram. The paravertebral muscles are then dissected subperiosteally from the lamina on the side of the lesion and *with a Hibbs retractor are retracted laterally to expose the laminae and articular facets* A small, blunt dissector such as a nasal septum dissector is inserted between the two laminae and the ligamentum flavum is gently depressed. In most cases, one is able to intensify the patient s pain by this maneuver and thus to assure the operator that the correct interspace has been exposed before any bone has been removed If no pain is produced by this maneuver it is best to review one s position before proceeding with the operation With small pointed *rongeurs, a portion of the upper lamina 0 5 cm long and 1 cm. wide, is removed.* The ligamentum flavum is grasped with forceps and dissected out The nerve root is injected with one per cent procaine, and a similar amount of the lower lamina and the medial edge of the facet is removed preferably by the use of a small, sphenoid punch. This produces a bony defect approximately 1 by 2 cm which is sufficient to expose the compressed nerve root and the lateral edge of the dura. The nerve root is easily visualized by removal of the epidural fat, though this is not always necessary it will be flattened out and pushed posteriorly by the herniated nucleus, thereby completely filling the intervertebral foramen and making insertion of a probe into this foramen difficult. Small pledgets of cotton attached to black silk sutures for identification, are packed above and below the root to control bleeding By careful blunt dissection, the nerve root is next separated from the herniated nucleus and retracted upward or downward, depending upon the direction of the herniation Usually proximal retraction of the root affords the best exposure of the mass. If the herniation is soft, the capsule formed by the posterior longitudinal ligament is incised and the loose fragments of nucleus are easily removed A small blunt hook is then inserted into the cavity of the disc and other loose fragments, if present, are removed One should be particularly careful to search medially for the loose fragments of the nucleus. If the lesion is hard i e., of long stand

ing it must be removed with a drill curette, dental chisel, or pituitary rongeur This is a difficult procedure and must be carried out with extreme care to avoid damage to the nerve root and cord

After removal of all of the protruding mass, a probe should be inserted into the intervertebral foramen If the nerve root is still not free an additional portion of the articular facets is removed until the probe can be inserted with ease, thus assuring complete decompression of the nerve root The cotton pledgets are then removed and if bleeding still occurs, it is controlled with small pieces of Gel foam dipped in a solution of thrombin Because of the possibility of a quadriplegia from a postoperative hemorrhage the wound is drained with a small Penrose drain for twelve hours.

After Treatment.—The patient is allowed out of bed as soon as the pain has abated to the point of toleration This varies considerably, some patients are able to be up as early as the second postoperative day whereas others remain in bed a week or longer Most patients will complain of numbness in the area supplied by the involved root this may continue for several weeks. A few have considerable weakness in the arm and hand and radicular pain for as long as ten days. In two of the author s cases, wherein both the fifth and sixth discs were removed pronounced weakness and hypesthesia persisted for two to three months.

The patient is allowed to return to work after one month being instructed to avoid heavy lifting As a rule, no support or physical therapy is necessary

LESIONS OF THE SPINOUS PROCESSES OR SPINOUS LIGAMENTS

Occasionally one observes a patient with an acutely painful area directly over or adjacent to a spinous process. Destructive lesions, such as metastatic tumors or localized osteomyelitis, may be responsible for the symptom, or, in rare cases, the pain may be induced by kissing spinous processes, elongation of a spinous process, or calcareous deposits in the supraspinous or inter spinous ligaments.

Kissing Spines

The normal interval between adjacent spinous processes may be dimin ished from postural changes, such as exaggerated lordosis, from destructive lesions of the bodies of the vertebrae, or as a result of a congenital abnormal ity If the two spinous processes are in contact a painful pseudoarthrosis, readily discernible in the roentgenogram, may follow

Treatment consists of arthrodesis or excision of the contiguous spinous processes, preferably the latter

Technic.—A three-inch longitudinal incision is made on either side of the midline and the deep structures are incised directly over the bony prominence of the two involved spinous processes. These structures are exposed subperiosteally the supraspinous and interspinous ligaments divided transversely above and below and, with bone-cutting forceps or rongeurs, the two spinous processes are excised at their bases. The paravertebral muscles are sutured over the defect.

Elongated Spinous Process

Rarely a true elongation of a spinous process, probably of congenital origin is associated with an otherwise normal spine Palpation may reveal an acute tenderness over the osseous protuberance. Treatment consists of

excision of the elongated process. In addition there is, as a rule, an adventitious bursa between the spinous process and the skin, which is also excised in toto

Technic.—(See p 1278)

Calcareous Deposits

Calcareous deposits in or adjacent to the supraspinous or interspinous ligaments, or calcareous deposits and adventitious bursae over the spinous processes, may also be a source of pain. These may or may not be discernible in ordinary lateral roentgenograms for osseous pathology In such cases, a blood uric acid test should always be made to determine the presence of gout. The following is a report of a typical lesion.

CASE REPORT —Mrs. T M., aged forty-six years, gave a history of low back pain for a period of ten to fifteen years. During the previous two or three months, the pain had been severe and constant. Examination revealed little of significance except a small, tender mass over the spinous process of the third lumbar vertebra. On exploration, a small bursal sac, 1.5 cm. in diameter, was found below the deep fascia and attached to the spinous process of the third lumbar vertebra. This sac contained a pasty calcareous deposit. Complete relief followed excision of the bursa.

GOUT

In a majority of cases, gout responds well to conservative measures. By adhering to a strict regime, patients may postpone acute attacks indefinitely and perhaps avoid any of the orthopedic complications associated with the disease

Rarely in chronic or severe cases, large uric acid tophi may be deposited in the soft tissues of the extremities, necessitating surgery because of (1) interference with the function of joints incident to pain or mechanical disturbance, (2) impending ulceration, if the tophi are large, (3) interference with the wearing of gloves or shoes, and (4) cosmetic appearance. In a series of cases studied by Linton and Talbott, less than 10 per cent of the patients required surgery

In view of the incidence of arteriosclerosis in gouty patients, an adequate blood supply should be maintained. Tourniquets may be employed in the upper extremity but are contraindicated in the presence of arteriosclerosis of severe degree in the lower extremity An atraumatic technic is essential. Tophic deposits in the fingers, hands, toes, or feet should be removed by single or multiple transverse incisions. One should be careful to avoid severing the digital arteries otherwise, sloughing of the skin may be an undesirable postoperative complication This same type of procedure may be entirely satisfactory for the removal of olecranon bursa or tophic deposits in the forearm, wrist or heel.

Technic (Linton and Talbott)—The incision is made directly over the tophus. The parchment thin skin is separated from the deposit by sharp dissection, and the skin edges are retracted by means of sutures. The deposit, together with its capsule, may be removed by excision or by curettage with a small bone curette or a combination of these two methods may be used, the major portion of the deposit being excised and the remainder being removed with a curette. The choice between these methods depends upon the location and size of the tophus. If the deposit involves the bones or tendons, the major portion of the tophus is usually excised and the remainder is removed from the tendon by a curette, in order to preserve the tendon or bone structure.

In some cases, the destruction of the bone may be so extensive that amputation of the toes or fingers may be necessary. Occasionally ulcerating tophic lesions may be so large and the skin so widely involved in the process, that a rather massive or block dissection will be necessary, leaving a raw area which must be covered by a split skin graft.

After Treatment.—Linton and Talbott have found that surgical wounds in gouty patients heal exceptionally well. They have also observed, however, that patients frequently develop a gouty arthritis associated with fever and leucocytosis on the second or third postoperative day. This complication may be avoided by the preoperative and postoperative use of colchicine and the other conservative measures usually employed in the treatment of gout.

In following ninety three patients with tophic deposits who were operated upon, Linton and Talbott observed only three who had recurrences of any significance.

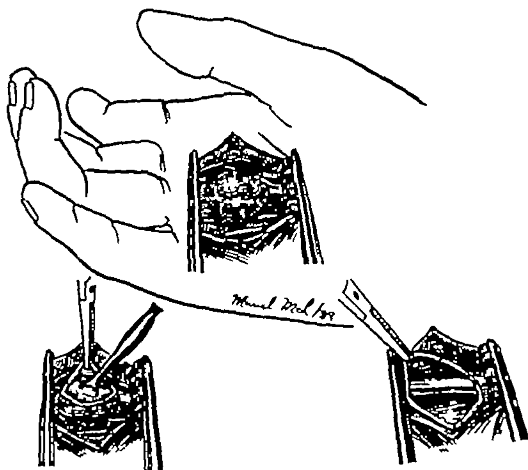


Fig. 596.—Removal of gouty tophus from flexor tendons. Capsule and deposit partially excised. Remainder removed from tendons with curette. (From Linton, R. R., and Talbott, J. H.: Ann. Surg. 117: 161, 1943.)

SYPHILIS

Tertiary lesions of syphilis which manifest themselves in the joints are observed with diminishing frequency, as the disease is now being detected in the early stage and efficient treatment instituted. Lesions of the joints usually respond to intensive antisyphilitic therapy.

If, following subsidence of the systemic disease, residual destruction of the joint and disability remain, operative treatment as for other low grade affections may improve the mechanical status of the joint.

If the pathologic process is primarily in the synovial membrane, even though this structure is markedly thickened with abundant villous formation, the articular surfaces of the joint may be only slightly affected In this type, an adequate degree of function may be restored by synovectomy (p 839)

PARASYPHILITIC ARTHROPATHIES—TROPHIC AFFECTIONS OF JOINTS—CHARCOT'S JOINTS

Trophic disturbances occur most often in the weight bearing joints, being in the majority of cases, the result of tabes dorsalis. Spontaneous fractures and crushing of the articular surfaces lead to deformity and instability of the joints. Conservative measures, such as intensive antisyphilitic therapy are preferable if deformity is not severe the patient may be enabled to walk with a brace.

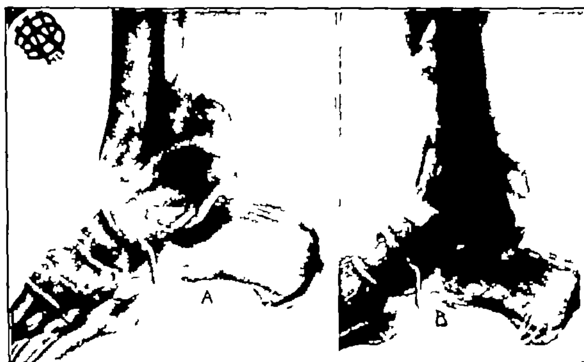


Fig. 497 —*A* Charcot ankle joint. *B* Eight months after anterior fusion.

Operative procedures should be undertaken with great caution and only after conservative measures have failed If the deformity interferes with function, however correction of deformity and arthrodesis may be employed in the ankle or knee Even though fusion may not be secured because of the excessive eburnation of the bone realignment of the joint and the use of a brace may be beneficial.

Key adopts a conservative attitude toward surgery on Charcot s joints. He advises that prior to operation on any joint of this type, one should consider the following factors

1 The patient should be prepared for a long period of hospitalization.

2. The general condition of the patient, particularly the genito-urinary tract should receive detailed attention the patient should be able not only to survive the operation and convalescence, but should have an excellent prospect of using the extremity if the procedure is a success.

3 The possible development of another Charcot's joint should be kept in mind especially when arthrodesis or an amputation is being considered

4 Arthrodesing procedures should not be performed during the progressive or early stages of a Charcot's joint

ANKLE

Fusion is accomplished by the technic described in Chapter XX A leather lacer brace reinforced by steel bars, should be worn constantly for a period of months, or until the roentgenograms demonstrate solid osseous union.

KNEE

The procedure which gives the best prospect of a successful fusion consists of (1) resection of the articular surfaces to obtain adequate approximation with the knee in good alignment (2) a sliding inlay bone graft which extends beyond the joint to normal bone (Albee) and (3) the insertion of small Steinman pins across the joint (Henderson) to insure immobilization Cleveland reports five cases, in three of which fusion was obtained by the Hibbs method (p 940) In the remaining two, the attempt to fuse the knee joint failed In one of the latter fusion was subsequently accomplished by sliding grafts after seventeen months of immobilization.

Following operation, a leather lacer brace extending from the groin to the toes, should be worn for at least a year or until the final mechanical status of the joint, whether union or nonunion is established In the event of nonunion, the brace may be retained to support the extremity in walking

Having observed the difficulty with which most surgeons obtain a solid arthrodesis in a Charcot's joint Soto-Hall has suggested a new technic The procedure is essentially a two-stage operation The first stage wherein multiple holes are drilled into the bone, is designed to counteract the avascularity and sclerosis of the bone adjacent to the knee joint and improve its blood supply

Technic —*After exposing the joint through an ordinary parapatellar incision* a drill four inches long and one-fourth inch in diameter is introduced into both the condyles of the femur and tibia in a fan shaped distribution. The drill should extend up and down the shaft of the femur and tibia into the intramedullary cavity for at least three or four inches.

Following this operation the leg is immobilized for a period of four to six weeks thereafter a standard arthrodesis is carried out Soto-Hall believes the poor results from arthrodesis upon Charcot's knee joints is attributable to the poor blood supply and sclerosis of the osseous tissue rather than to any inherent loss in the process of tissue repair reaction and regeneration

HIP

Fusion is difficult to obtain in the hip under the most favorable circumstances, and the presence of a syphilitic arthropathy adds immeasurably to the problem For this reason arthrodesis is seldom advisable A subtrochanteric osteotomy as employed for ununited fractures of the neck of the femur or a Schanz osteotomy may provide sufficient *stability for ordinary* activity Reconstruction operations (Chapter X) have also been advised

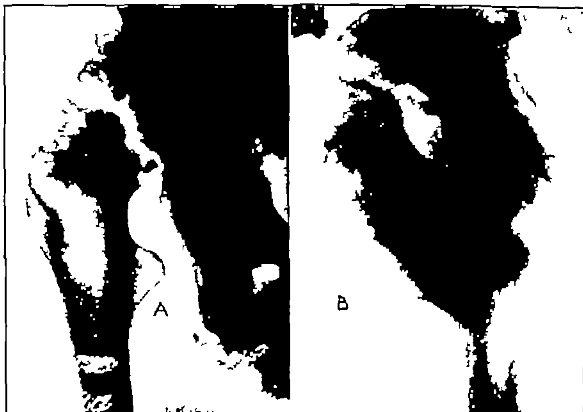


Fig 591.—*A* Charcot's hip joint. *B* Two and one-half years following Schanz osteotomy Excellent functional result.

SPINE

Charcot's joint of the spine is a relatively rare condition. Occasionally however destruction of the vertebrae is so extensive as to produce a mechanically weak spine with symptoms which justify fusion.

EPIPHYSITIS OR OSTEOCHONDRITIS

These terms are applied to affections of the epiphyses which develop during the period of most active growth The lesion may be localized to a single epiphysis, or may involve two or more simultaneously or successively The etiology is unknown, although any of the following factors may be responsible (1) trauma, (2) infection, (3) congenital malformation, and (4) endocrine disturbances Recent work would indicate that probably most of these disturbances are of endocrine origin Hypothyroidism has a definite relationship to coxa plana the use of thyroid extract has hastened the healing period In certain of the intra articular and extra-articular epiphyses, the affection presents manifestations so characteristic as to be regarded a definite clinical entity In other joints, on the contrary, intra-articular epiphysitis may closely resemble other diseases, necessitating a careful differential diagnosis

Although any of the epiphyses may be involved the treatment of only those wherein surgery is commonly employed will be described.

Epiphysitis of the Metatarsal Bones—Köhler's Disease—Freiberg's Infraction

This entity is observed most commonly in the head of the second metatarsal bone. The disease, however is not limited to the second metatarsal

bone having been observed in the third by Campbell and in the fourt[h]
fifth by others.

Operative procedures are not advisable in the acute stage. Afte[r]
process has subsided, excision of the head of the bone may be indicate[d]
cause of continued pain and disability

Excision of the Head of the Second Metatarsal Bone

Technic.—A dorsal incision two inches in length is made just later[al]
the midline of the affected joint, beginning over the distal extremity o[f]
metatarsal bone and ending over the proximal extremity of the first pha[lanx]
The extensor tendon is retracted medially and the joint capsule is op[ened]
longitudinally exposing the flattened head of the bone. Any loose b[odies]
should be removed With bone-cutting forceps the head of the meta[tarsal]
bone is resected and all bony particles are removed

After Treatment.—The stitches are withdrawn on the ninth day and [walk-]
ing is begun with the aid of an arch support, and a metatarsal pad. [If]
dorsal contractures with some degree of pain and permanent disability
follow active and passive plantar flexion of the toes should be diligently [prac-]
ticed.

Results of this procedure are not always satisfactory although pai[n and]
disability are usually relieved to some extent. If symptoms persist [after]
excision of the head removal of the entire bone and amputation of the [cor-]
responding toe may be necessary together with osteotomy of the adj[acent]
bones as described for tuberculosis of the metatarsal bones (p 909)

Fusion of the Midtarsus for Epiphysitis of the Scaphoid Bone (Köhler s Disease)

After osteochondritis of the scaphoid bone, pain and disability ma[y de-]
velop from the following changes flattening of the head of the astra[galus]
with fibrillation of the articular cartilages, formation of osteophytes [at]
the margin adjacent to the articular surface, and distortion and dimin[ution]
in size of the scaphoid, with sclerosis and increased density of the bo[ne]

If the symptoms persist, operation is indicated. Arthrodesis is the
treatment of value in this joint. The midtarsal joints (astragaloscapho[id]
calcaneocuboid) may be fused by a technic similar to that employed f[or de-]
formities incident to poliomyelitis (p 1320) As function of the calcaneoc[uboid]
joint is almost obliterated when the astragaloscaphoid joint is fused res[ection]
and arthrodesis of this joint should also be carried out. The end resul[t is]
excellent. In a large percentage of cases the patients are entirely fr[ee of]
symptoms and, aside from loss of lateral movement, are afforded natur[al use]
of the foot, with normal endurance

Epiphysitis of the Tibial Tubercle—Osgood-Schlatter s Disease

Surgery has been recommended in epiphysitis of the tibial tubercl[e]
inducing union of the tuberosity to the tibia and arresting the process.
dom however are such measures advisable healing will take place wi[thout]
any treatment in practically every case. Of 106 patients with epiphysi[tis of]
the tibial tubercle, we have advised surgery for only two in bo[th of]
whom the process was active and extremely painful. One of the patie[nts, a]
girl aged eighteen years, declined the operation. The other a boy aged s[ix-]
teen years, obtained an excellent result by an autogenous bone peggin[g]

eration. The procedure is simple and practically without complications, but is indicated only in patients sixteen years of age or older when pain is exaggerated and fusion of the epiphysis is delayed

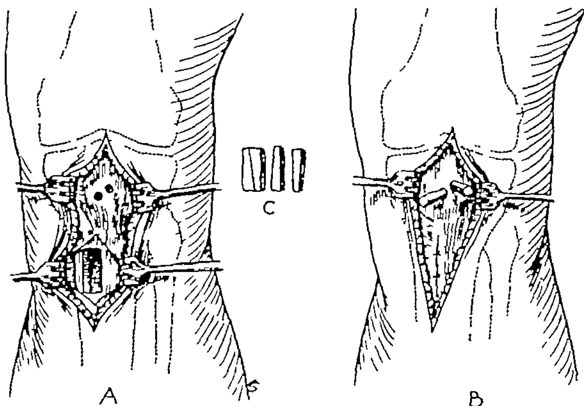


Fig. 599.—Technic of pegging of tibial tubercle for Osgood Schlatter's disease. (Redrawn from Bosworth, D. M.: J. Bone & Joint Surg. 16: 829, 1934.)

Autogenous Bone Pegging of the Tibial Tubercle

Technic (Bosworth).—The incision is carried downward over the lower third of the ligamentum patellae and tibial tubercle, then distally on the tibia for three inches. Two match stick bone pegs, four centimeters long are cut from the tibia with an electric saw the base of each peg being larger than the tip. Two holes are drilled one near though not in contact with the proximal tibial epiphyseal plate and slanting upward and outward the other distal to the plate, and slanting upward and inward. The pegs are inserted into these holes, maintaining the tubercle snugly against the tibial shaft, and their projecting portions are removed.

After Treatment.—A plaster cast is applied from the groin to the toes and retained for two and one half weeks. Following its removal, walking is instituted.

Removal of Ununited Tibial Tubercle

During the war one of us (H. Smith) observed two cases in adults wherein the tibial tubercle had failed to unite and functioned as an accessory patella. The rather large ossicle of bone was an integral part of the patellar tendon and had a definite, irregular fibrocartilaginous pseudarthrosis with the tibia. Removal was necessary because of pain incident to excessively rigorous exercise.

Technic.—Through an anteromedial incision two and one-half inches long the medial border of the patellar tendon is exposed retracted laterally and

evaginated The bony ossicle, thus exposed, is dissected away from the patellar tendon by sharp dissection The contiguous surface of the tibia is scarified the cartilaginous surface removed, and the patellar tendon sutured to the scarified area The ossicle is removed without disturbing the distal attachment of the patellar tendon to the tibia.

After Treatment.—The knee is immobilized for a period of two weeks At the end of that time active exercises are instituted

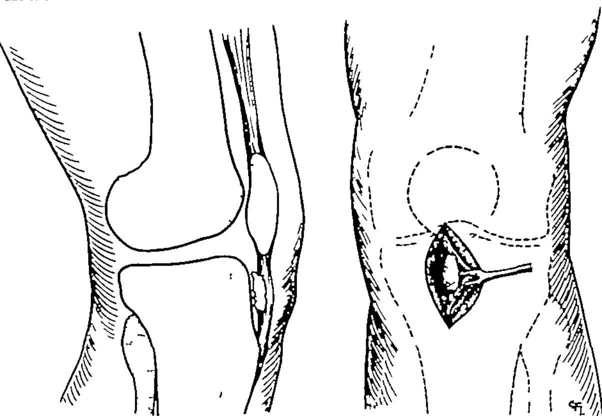


Fig 660—Technic of removal of ununited tibial tubercle.

COXA PLANA

A relatively high percentage of excellent anatomic and functional results is obtained by bed rest, as advocated by Danforth The pathologic process may be prolonged for two or three years before restoration of the head is complete.

Drilling of the Upper Femoral Epiphysis

Drilling of the upper femoral epiphysis has been employed by Bozsan and Ferguson and Howorth in an effort to shorten the period of recovery These authors believe that coxa plana is brought about by a disturbance of circulation to the head of the femur secondary to inflammatory changes in the soft tissue, and that revascularization may be hastened by the formation of channels across the epiphysis from the neck of the femur Sufficient roentgenographic evidence of satisfactory end results has not been produced however to justify recommendation of the operation routinely

Technic (Bozsan).—The outer side of the trochanter is exposed through a lateral incision three inches in length. A hand drill 7/64 inch in diameter and 5⅞ inches in length is used. The direction and depth of the drill channels are estimated by palpation. Holes should not be drilled below the lesser trochanter nor above the middle of the greater trochanter further the

epiphyseal plate of the greater trochanter should be avoided Only two or three channels are formed through the epiphyseal plate between the head and neck as more than this might induce premature ossification of the epiphysis. (*Note* *Roentgenographic control should be employed to insure* efficient performance of this procedure.)

After Treatment.—A plaster spica cast is applied After eight weeks, the cast is bivalved and active exercises are instituted Weight bearing is discouraged for one year

Technic (Ferguson and Howorth)—The hip is exposed by an anterior iliofemoral incision, and a section of the capsule is excised Just distal to the epiphysis a window of the cortex is removed from the neck of the femur and conserved for laboratory study With a curved awl, several holes are drilled through this opening in various directions into the head of the femur The opening is closed with a bit of muscle for hemostasis.

***After Treatment.**—See above.*

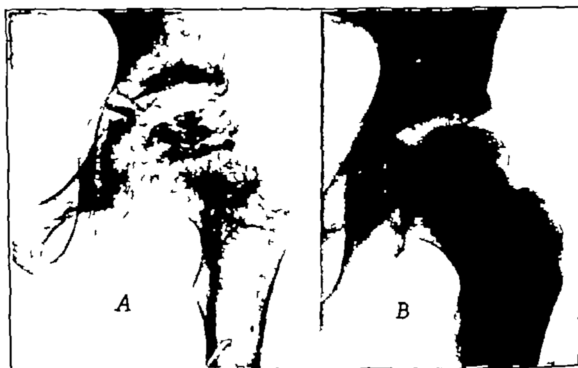


Fig. 401.—*A* Typical coxa plana. *B*, End result three years later Treated conservatively by bed rest, according to Danforth no immobilization.

Howorth states The operation has been found most useful in the progressive stage and in the early stage of repair The total amount of degeneration and the residual deformity appear to be reduced and the period of convalescence shortened about one-third. No new degenerative areas appeared and repair began promptly after the operation The operation must be combined with a period of some months of non weight bearing in order to be effective. Better results were obtained in the group operated upon than in the other groups.

Residual Stage of Coxa Plana

In untreated cases, or those in which response to treatment has not been favorable, the hip may be fixed in flexion and adduction. Plastic operations



Fig 60 —A Typical coxa plana. B Seven years after treatment by non-weight-bearing. C Practically normal hip, both functionally and anatomically 1 years after onset of symptoms.

on the soft structures (Chapter XVI) or subtrochanteric osteotomy may be utilized to correct the alignment of the extremity Operative procedures which directly involve the head of the femur are not indicated until fusion of the epiphysis has taken place as growth ensues, the head and neck of the femur may become so distorted that function of the hip is materially impaired. Essentially the same procedures are employed for this status as for coxa malum (p 851)

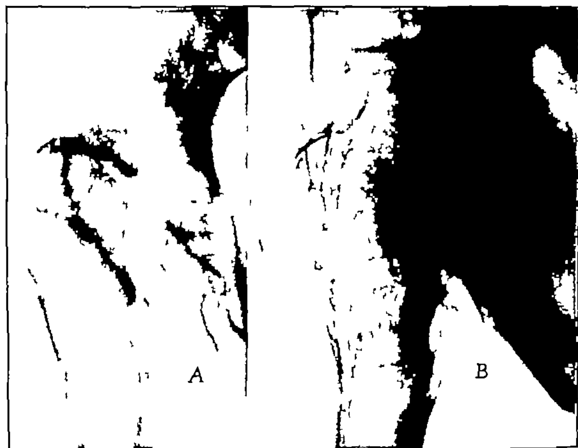


Fig. 491 —A Neglected coxa plana with marked incongruity of articula surfaces. B After fusion of hip joint.

SLIPPED UPPER FEMORAL EPIPHYSIS*
(EPIPHYSEAL COXA VARA)

This affection is most common in boys between the ages of ten and seventeen years The process is frequently observed in the effeminate, obese type, with underdeveloped genitals (Fröhlich s syndrome) On the other hand, the affection may be preceded by excessively rapid growth in a tall, angular individual. The exact etiology of this process is unknown Many authors have felt that hypopituitarism may be responsible. This is questionable, as the excess weight in these individuals probably predisposes to slipping of the epiphysis. In tall rapidly growing individuals, the bone may be formed faster than it can mature In this event the bone adjacent to the epiphyseal line may be

* To avoid controversy confusion, and a maze of variations in indications and technic, we have prepared the following section on the treatment of slipped upper femoral epiphysis as carried out in this clinic. Priority for some of the more or less standard technics is difficult to establish. Suffice to say we claim no particular originality for any minor variations of these well understood procedures. The reader is referred to the bibliography at the end of the chapter for a comprehensive review of contemporary methods of treatment.

soft, weak and immature. Under these conditions the stress of weight bearing and repeated minor traumata are probably the principal etiologic factors.

The prognosis of slipped upper femoral epiphysis is always doubtful as subsequent changes in the head cannot be estimated particularly in old or neglected cases. Apparently, the more radical the procedure the more likely a poor end result Following open or closed reductions, the head may become a mass of aseptic, necrotic bone or the bone may undergo necrosis in one or more areas, causing a gross irregularity of the joint surfaces, with subsequent changes in the entire articulation In neglected cases, or even following efficient treatment, the head may gradually become broad flat, and irregular, the diameter of the neck increased and bowed forward, and the cartilage over the lower portion of the head may disintegrate

For the purposes of discussion and treatment the patients are divided into five groups, according to the following pathologic conditions

Type I.— Early gradual slipping of the upper femoral epiphysis in which the epiphysis has migrated on the neck for a distance of less than one-third of the diameter of the neck

Type II — Gradual slipping of the epiphysis with displacement of one-third or more of the diameter of the neck of the femur

Type III.—Malunited slipped upper femoral epiphysis

Type IV — Traumatic dislocation of the upper femoral epiphysis

Type V — Old malunited slipped upper femoral epiphysis, with hypertrophic arthritic changes, and possibly coxa malum

In the first and second groups, i e the gradual slipping of the upper femoral epiphysis, the epiphysis is never actually loose on the neck, nor at any one time does it slip any appreciable distance as the head gradually migrates downward and posteromedially Callus forms at the junction of the epiphysis, with the neck on the posterior and inferior aspect as the deformity progresses Fusion of the epiphyseal line in a neglected case gives rise to the third and fifth conditions enumerated above The fifth type is in essence a Type III subjected to the passage of time and wear i e a coxa malum

Traumatic dislocation of the upper femoral epiphysis (Type IV) may be the result of trauma of sufficient force to displace a normal upper femoral epiphysis in the majority of cases, however the trauma is superimposed upon a gradually slipping epiphysis.

In our experience the prognosis in the early cases, with slipping of less than one third of the diameter of the neck, has been excellent In cases with slipping of more than one third of the diameter of the neck (Type II) and those with malunited (Type III) slipped femoral epiphyses, wherein cuneiform osteotomies have been performed through the neck of the femur the results have been excellent in about 60 per cent of the patients fair in approximately 25 per cent and poor in the remainder In Type IV acute traumatic dislocation of the upper femoral epiphysis, the prognosis is poor in that following this condition, aseptic necrosis of the epiphysis usually occurs regardless of the treatment employed Rarely the epiphysis may be manipulated back into position by the method used for fracture of the neck of the femur As a rule however the epiphysis cannot be accurately manipulated into position vigorous manipulation should not be employed in the attempt to reduce the epiphysis. In these cases, open reduction combined with internal fixation is preferable

The treatment and prognosis of coxa malum (Type V) are discussed under hypertrophic arthritis of the hip

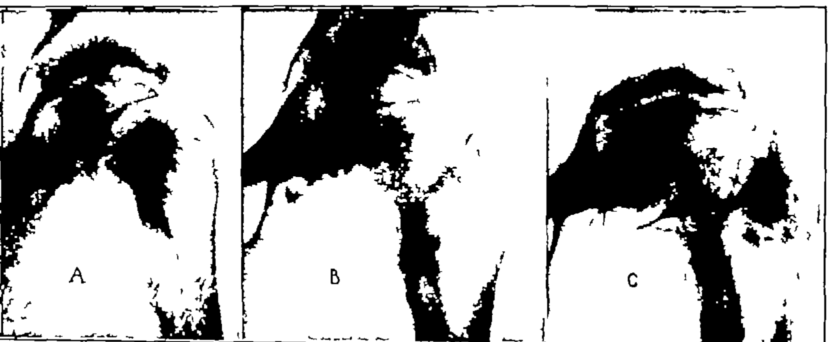


Fig. 604.—*A* Separation of upper femoral epiphysis. *B* Reduction by Whitman maneuver hip immobilized in double spica cast. *C* Five years later marked incongruity of articular surfaces, and distortion and malformation of head of femur Except for relatively recent traumatic separation, closed manipulation is highly inadvisable.

Early Gradual Slipping of the Upper Femoral Epiphysis (Type I)

In Type I, wherein the upper femoral epiphysis has gradually slipped one-third or less of the diameter of the neck, it is our opinion that internal fixation should be employed without opening the hip joint or without the previous use of traction or manipulation to correct displacement Wilson, Badgley Martin, and others have utilized the Smith Petersen nail for this purpose Howorth utilizes bone pegs. We prefer Knowles pins In our experience, this type of internal fixation has prevented further slipping of the head and has aided premature closure of the epiphysis. In our patients, aseptic necrosis of the epiphysis has never followed this operation We feel that the insertion of the three Knowles pins produces less trauma to the epiphysis than is produced by a Smith Petersen nail Because of the size and contour of the capital epiphysis, it is not easy to insert a Smith Petersen nail so that it adequately engages the displaced head. In a young growing individual the bone is hard and the nail is inserted with much more difficulty than in an elderly individual with osteoporosis of the bones about the hip joint The use of Knowles pins however has two disadvantages (1) they are more difficult to insert than a single nail in that three or four pieces of apparatus must be lined up properly, rather than one (2) pins of a large variety of lengths must be available. The latter is important, as the capital epiphysis is thin and the pin must be long enough to protrude through the epiphyseal cartilage, yet not long enough to extend through the articular cartilage

Technic.—A short longitudinal incision is made over the lateral aspect of the thigh, beginning just distal to the tip of the greater trochanter (p 179) In the upper portion of the incision the fascia lata may be divided posterior to the fibers of the tensor fascia femoris muscle thus avoiding splitting of the muscle This brings the vastus lateralis muscle into view Beginning at the upper point of the origin of the vastus lateralis on the lateral aspect of the femur the muscle fibers are divided for a distance of approximately one and one-half inches along the lateral surface of the shaft of the femur The muscle is then reflected to expose the lateral aspect of the shaft of the femur Three Knowles' pins are inserted through the neck of the femur and into the epiphysis. A guide pin is first passed through the trochanter and neck of the femur into the epiphysis, by the technic employed for nailing a fracture of the neck of the femur Check up roentgenograms are then made. If the wire is in satisfactory position the correct length of the Knowles' pins is estimated Using the wire as a guide three Knowles pins are next passed from the lateral aspect of the femur into the epiphysis. The pins should be placed parallel to each other each at one angle of an equilateral triangle, one at the anterosuperior aspect, one at the posterosuperior aspect, and the other at the inferior aspect of the femoral neck. The pins should be of proper length to penetrate the epiphysis, but not to pierce the articular surface of the head of the femur One must keep in mind the fact that the epiphyseal line is slightly convex, and a pin which appears to be in the center of the epiphysis may not have crossed the line Roentgenograms should be made prior to closure of the wound to verify position of the pins.

After Treatment.—If the epiphysis has slipped approximately one third of the diameter of the neck, a cast is applied from the nipple line to the toes, and to the knee on the unaffected side with the thigh in neutral rotation and moderate abduction The use of the cast for two to three weeks prevents external rotation of the thigh In patients with a minimum degree of epiphyseal displacement a cast is unnecessary

The patient is kept in bed for three to four weeks. Quadriceps exercises are begun within two to three days after the operation. If a cast is used, a window is placed over the knee to allow these exercises. Active exercises consisting of flexion and extension of the thigh and knee are instituted during the second week following the operation. Walking with crutches, the foot being placed on the floor but without weight bearing through the hip is permitted four weeks following the operation. Two to four weeks later partial weight bearing with crutches is allowed. Full weight bearing without crutches is not permitted until four to six months following the operation.

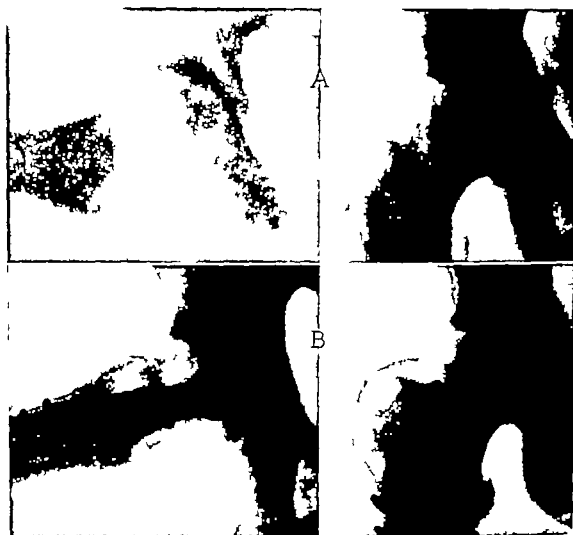


Fig. 605.—Early gradual slipping of the upper femoral epiphysis (Type I). *A*, Epiphysis has migrated on neck for a distance of less than one-third of diameter of neck. *B*, Five years after insertion of Knowles pins under roentgenographic control.

Gradual Slipping of the Epiphysis With Extensive Displacement (Type II)

In Type II, wherein the capital epiphysis has migrated one-third or more of the diameter of the neck, the displacement of the epiphysis is sufficient to produce permanent irregularities in the head of the femur and in the acetabulum. With these facts in mind, some form of reconstructive operation is usually indicated. Two general types of operations have been suggested for this condition: (1) an osteotomy through the neck of the femur with correction

of the primary deformity, (2) an osteotomy through the trochanteric region The former is advantageous, in that the primary deformity is corrected By the latter procedure the primary deformity is counteracted by a deformity in the opposite direction In using the first (osteotomy through the neck), the possibility of aseptic necrosis with a resultant arthritis of the hip or even an ankylosis, must be borne in mind The trochanteric osteotomy has a better prognosis from a physiologic standpoint, as the blood supply of the head and neck of the femur is not impaired In Type II deformities, the cuneiform osteotomy through the neck of the femur is usually preferable

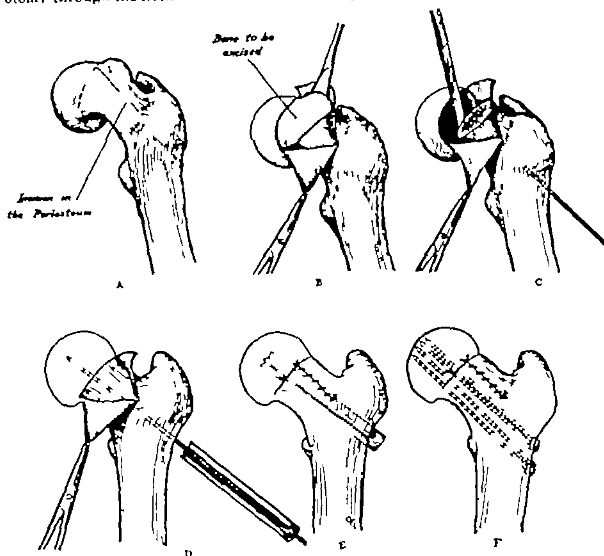


Fig. 606.—Cuneiform osteotomy (Martin) for gradual slipping of upper femoral epiphysis with extensive displacement (Type II) *A* Line of incision through soft tissue investments of head and neck. *B* Shaded area represents cuneiform wedge of bone to be excised. *C* Guide pin inserted prior to reduction. *D*, Neck apposed to epiphysis in proper alignment and position. Guide pin properly placed prior to insertion of Smith-Petersen nail. *E* Operation complete. (From Martin, P H.: J Bone & Joint Surg. 30-A 9 1948) *F* Technic described in text. Knowles pin being used in preference to Smith Petersen nail.

Cuneiform Osteotomy of the Neck of the Femur

Technic.—The hip joint is exposed through a Smith Petersen approach (anterior iliofemoral) the capsule is retracted bringing into view the upper portion of the neck of the femur The proximal and anterior edge of the neck of the femur from which the epiphysis has slipped is brought into view By external rotation of the thigh the anterior margin of the epiphysis is visualized In order to correct the deformity a wedge of bone must be resected from the

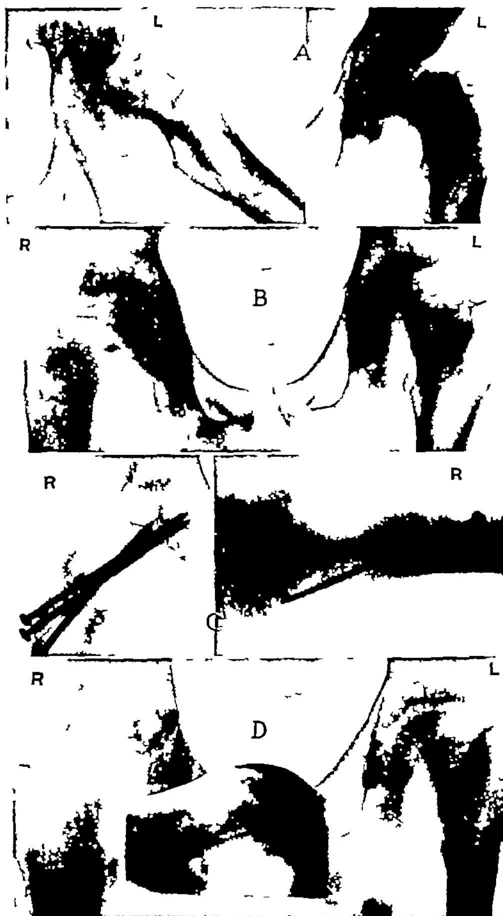


Fig. 467.—(See opposite page for legend.)

anterior and superior portion of the neck The apex of the wedge must be located at the posterior inferior portion of the neck of the femur the widest portion of the wedge is located at the anterosuperior aspect of the neck just lateral to the epiphyseal line. Usually, the base of the wedge is approximately 1 to 1.5 cm wide, depending upon the amount of slipping which has occurred In the presence of extensive displacement the epiphysis *assumes a more posterior and*



Fig. 606.—*A*, Type II slipped upper femoral epiphysis. *B* Four months after cuneiform osteotomy and internal fixation. Epiphysis is fused, joint space is good, contour of head is normal. *C* Beginning arthritic changes seven months after operation. *D* Advanced arthritic changes three years after operation patient will eventually require nvold arthroplasty

Fig. 607.—*A*, Epiphyseal separation of head of left femur Pain in hip for two weeks prior to injury Patient first observed approximately six weeks after separation. *B* Thirteen months after cuneiform osteotomy left hip beginning separation of upper femoral epiphysis, right hip. *C*, Right hip three months after open reduction and internal fixation. *D*, Left hip two and one-half years after operation right hip one and one-half years after operation. Pa tient has relatively little disability in either hip and is able to participate in athletics, but walks *with a moderate limp from shortening of the left extremity*

inferior position thus, the base of the wedge required for correction must be wider Sufficient bone must be removed to allow an easy reduction without tension The base of the wedge having been outlined with an osteotome, small ribbon retractors are placed around the neck of the femur In completing the osteotomy the osteotome should not be allowed to slip through the posterior and inferior aspect of the capsule as damage to the capsule in this region will interfere with the blood supply to the head The retractors should serve as a guard to protect the capsule Before the wedge of bone is cut, a threaded guide wire or Knowles pin is drilled into the epiphysis to enable the operator to control the position of the epiphysis after the osteotomy has been completed. With a thin, narrow osteotome the wedge of bone is then removed. Resection is accomplished by repeated small advancements of the osteotome along the osteotomy lines on both sides of the contemplated wedge This prevents the bone from spreading and permits removal of the wedge in one segment The epiphysis is then rotated into its normal position in the acetabulum by means of a threaded pin The epiphysis is held in this position while the osteotomy site is closed by internal rotation of the leg The osteotomized portion of the neck is brought in contact with the osteotomized surface of the epiphysis. After the wedge has been accurately closed the epiphysis being in normal relation to the neck, a short lateral incision is made over the trochanteric region three Knowles pins are than passed through the neck to hold the epiphysis in position The pins are inserted under roentgenographic control by the technic described for Type I To minimize the number of roentgenographic exposures, the pins may be placed through the neck when they appear at the osteotomy site the latter is closed and the pins are passed on into the head. Final films are necessary to check the length and position of the pins.

After Treatment.—A cast is applied from the nipple line to the toes on the affected side, and to the knee on the unaffected side, maintaining the thigh in neutral rotation and moderate abduction The cast is removed approximately four weeks following the operation Active and passive motion is then begun and gradually increased Approximately two weeks after removal of the cast the patient is allowed to begin walking with crutches, bearing the weight of the affected extremity on the floor but without bearing weight through the hip Partial weight bearing with crutches is permitted three to four months postoperatively and full weight bearing is instituted when the roentgenogram demonstrates union at the osteotomy site.

Malunited Slipped Upper Femoral Epiphysis (Type III)

In Type III lesions, the choice between osteotomy through the neck or trochanter depends on the age of the patient, the maturation of the epiphysis and the degree of deformity Trochanteric osteotomy usually is preferable in young adults with a closed epiphysis and a displacement of more than one-half the diameter of the neck of the femur This procedure affords an easier correction and subjects the patient to a minimum number of undesirable postoperative complications.

Conversely a few neglected cases of slipped upper femoral epiphysis with a partially obliterated epiphyseal line, are eligible for correction of the primary deformity namely young adults, or late adolescent patients with displacement of less than one-half of the diameter of the neck, and a moderate or minimal external rotation deformity The mechanical advantage of correcting the fundamental deformity through the neck, in contrast to compensation by a deformity

through the trochanter in the opposite direction is obvious. Physiologic and pathologic contingencies, unfortunately, interfere with the mechanical preference. Correction of the deformity through the neck and head may be followed by aseptic necrosis of the head, and limited motion or ankylosis of the hip These undesirable sequelae provide a doubtful prognosis of this procedure consequently, cuneiform osteotomy through the neck is applicable to only a very limited group of Type III lesions

For correction of a coxa vara with a minimal external rotation deformity a symmetrical cuneiform trochanteric osteotomy is sufficient (p 1043) The width of the base of the lateral wedge should be commensurate with the amount of deformity

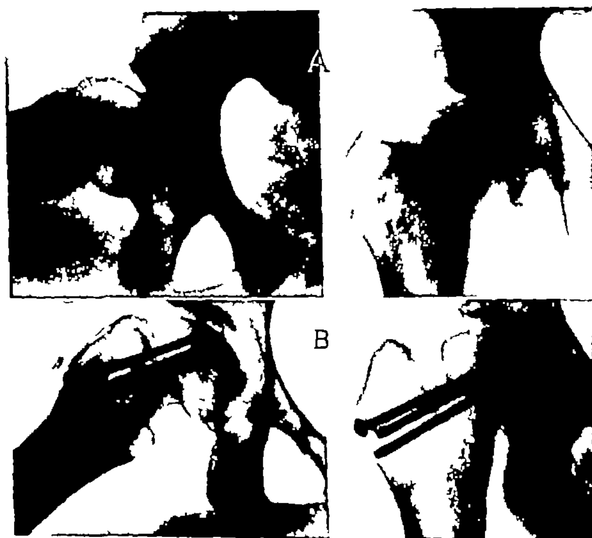


Fig. 469—A Type III slipped upper femoral epiphysis with marked rotation deformity B Good functional and anatomic result five years following cuneiform osteotomy of neck.

Simultaneous correction of a coxa vara, and a moderate or severe degree of external rotation deformity is more complicated Anteroposterior and lateral roentgenograms of the hip should be measured accurately to determine the exact degree of posterior displacement of the head on the neck, and the head neck and shaft angle. The coxa vara is corrected by a cuneiform lateral wedge the size of the wedge being predetermined from an anteroposterior roentgenogram The adducted or varus position of the head is compensated for by an abducted position at the osteotomy site. After union if the extremity is in neutral position

the head of the femur despite the head neck deformity is in a fairly normal relationship with the acetabulum

This same principle is applied to the posterior position of the head, as revealed in the lateral roentgenogram To establish the head of the femur in a horizontal position or in a neutral position with the acetabulum, the extremity must be maintained in an externally rotated position. To counteract the external rotation, two procedures may be employed (1) at the time of cuneiform osteotomy for coxa vara the distal portion of the limb is internally rotated, the degree of rotation being proportionate to the head neck deformity (2) a biplane cuneiform trochanteric osteotomy is carried out that corrects coxa vara, internally rotates the extremity, and compensates for the externally rotated position of the trochanter by angulating the extremity anteriorly at the osteotomy site The first procedure is simpler, the second is mechanically more correct but requires careful planning and is a difficult osteotomy to execute

Compensatory Trochanteric Osteotomies

Rough estimates of the angles of the osteotomy and the width of the wedge are likely to be inaccurate Measurements should be made from tracings of the preoperative roentgenograms. By paper cut-outs, the exact pattern of the osteotomy can be determined preoperatively Careful planning is particularly necessary for the biplane osteotomy

Trochanteric Cuneiform and Rotation Osteotomy—Through a lateral incision (p 179) the trochanteric region is exposed by reflecting the vastus lateralis and the intermedius upward and medialward from the lateral and superior aspects of the femur The bone is exposed from the insertion of the gluteus minimum above, downward for two and one-half to three inches. The cuneiform osteotomy is outlined on the anterior aspect of the femur using an osteotome. The width of the wedge on the lateral aspect of the femur determines the amount of coxa vara that will be corrected The wedge of bone is then removed with a small hand saw or with the reciprocating unit of a motor saw The former is the better as the latter tends to drift making it difficult to keep the two saw cuts perpendicular and the surfaces flat. After removing the bone wedge, the osteotomy is closed by abducting the thigh One of the conventional type of nails used in the treatment of trochanteric fractures is necessary to maintain the position of the fragments. Before fixing the plate portion of the nail to the shaft, the limb is internally rotated at the osteotomy site to the desired degree and subsequently fixed in the corrected position.

After Treatment.—A spica and a half cast may or may not be applied, depending on the security of the internal fixation. Usually a cast is not necessary Postoperative care more or less follows the treatment outlined for conventional trochanteric osteotomies (p 1043)

Biplane Cuneiform Osteotomy—The exposure of the operative field is the same as described above. The osteotomy is outlined so that it is widest on the anterolateral surface of the femur Its second widest point is the posterolateral aspect of the femur The third widest point is the anteromedial quadrant of the femur Its narrowest portion is a point on the posteromedial aspect of the femur The biplane cuneiform portion of bone is removed with a stiff-bladed hand saw with a blunt end. This procedure may be supplemented by multiple holes drilled in the line of the cuts, and with the use of an osteotome. After the wedge of bone is removed the osteotomy site is closed by abducting flexing and internally rotating the thigh. The position is maintained by internal fixation as

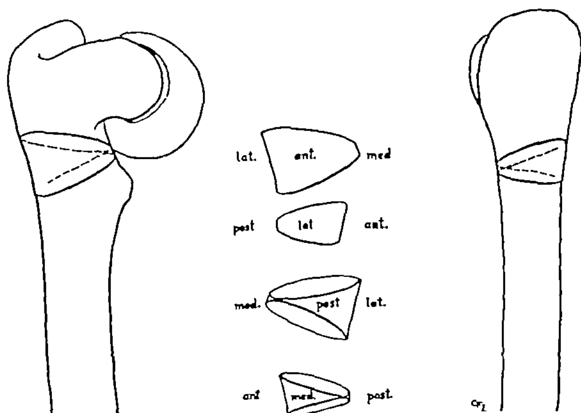


Fig. 610.—Diagram of trochanteric biplane cuneiform osteotomy

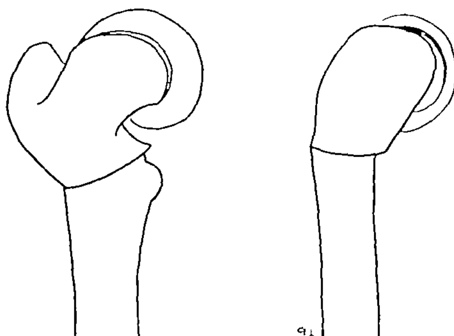


Fig. 611.—Same as Fig. 610. A. After removal of biplane cuneiform wedge, correction may be doubled by reinserting the wedge in the defect in the reversed position.

described above After removal of the wedge of bone the amount of correction can be doubled by rotating the wedge 180 degrees and placing it back in the osteotomy site. If this is done, additional internal fixation is required to hold the replaced wedge of bone in situ Also additional care is necessary to remove the wedge in one piece

After Treatment—The hip is immobilized by a cast which extends from the nipple line to the toes on the affected side and to the knee on the opposite side The hip joint is immobilized in slight abduction and neutral rotation and 160 degrees flexion the knee being flexed to the same degree. Immobilization is ordinarily continued for a minimum period of eight weeks. Subsequent treatment depends upon the progress of union at the osteotomy site, but in general follows the same pattern as for conventional trochanteric osteotomies (p 1043)

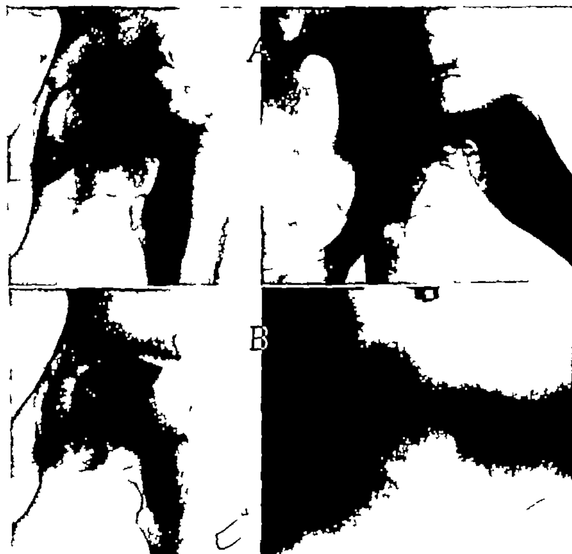


Fig. 612.—Type II slipped upper femoral epiphysis with excessive deformity, cuneiform osteotomy of the neck not advisable. *B* Position improved following biplane trochanteric osteotomy

Acute Traumatic Slipped Upper Femoral Epiphysis (Type IV)

Manipulation of the epiphysis into satisfactory position is usually impossible. The advisability of manipulation is questionable, unless the displaced epiphysis is recent, and can be reduced with ease.

Technic.—The hip joint is exposed through a Smith Petersen anterior ilio-femoral approach. By sharp dissection, the capsule is split longitudinally parallel with the anterior surface of the neck of the femur. The capsule is then detached from the rim of the acetabulum for about 1 cm on each side of the incision. The upper end of the neck of the femur is next exposed by small deep curved retractors passed around the neck of the femur. The loose epiphysis is displaced downward medially and posteriorly. By external rotation the anterior margin of the epiphysis is brought into view. A threaded wire, or Knowles pin is introduced into the anterior edge of the epiphysis, and thence into the central portion of the epiphysis. This wire is then used as a lever to place the loose, freely movable epiphysis into its normal relationship with the acetabulum. As the epiphysis is held in this position with a threaded wire, the anteriorly displaced neck of the femur is reduced into the epiphysis by internal rotation of the thigh. The epiphysis having been accurately replaced a second short longitudinal incision is made over the trochanteric region. Three Knowles pins are inserted by the technic described above for Type I. Final check up roentgenograms verify the position of the epiphysis, and of the pins.

After Treatment.—A cast is applied from the nipple line to the toes on the affected side and to just above the knee on the unaffected side, with the hip in neutral rotation and 160 degrees' abduction. The cast is removed after two to four weeks. The patient is then given instructions to increase, gradually active and passive motion of the hip joint. Usually the patient is required to use crutches, placing the weight of the extremity on the floor but not bearing weight through the hip for four to six months at this time weight bearing may be gradually resumed with crutches. As a rule unrestricted weight bearing is not permitted until the lapse of nine months to one year.

Residual Stage of Slipped Upper Femoral Epiphysis (Type V)

In the residual stage of epiphyseal separation, one is not concerned with an active disease but with the reaction of an incongruous joint to mechanical irritation. There may be only a slight irregularity of the contour of the head of the femur or distortion may be so extreme as to justify a diagnosis of coxa malum. In the latter event any of the procedures described above (p 851) may be employed. If the joint surfaces are relatively normal subtrochanteric osteotomy is particularly applicable in that the coxa vara deformity may be corrected and the line of weight-bearing placed more directly beneath the head, thus relieving pain.

CHONDROMALACIA OF THE PATELLA

Chondromalacia is a condition characterized by a degeneration of the articular cartilage of the patella and the contiguous surface of the intercondylar groove of the femur. Its common causes are acute or chronic trauma to the patella, osteochondritis dissecans, bipartate patella and arthritis.

Ralph Soto-Hall lists the pertinent diagnostic points as follows: Subpatellar crepitus on active movement, a variable deep-seated pain beneath the patella, tenderness on percussion of the patella, pseudolocking or ratchet rhythm, a subjective feeling of instability and an occasional recurrent subluxation of the patella.

In civilian life this syndrome is most often associated with a hypertrophic arthritis of the articulation between the patella and the femur. Roentgenograms of the knee may be negative except for osteophytes at the superior and inferior portions of the articular surface of the patella; on the other hand arthritis of the entire knee joint may be associated. In young individuals and athletes this

syndrome is usually caused by trauma perhaps of relatively insignificant degree During the war, chondromalacia of the patella was not infrequently associated with more severe traumatic lesions of the knee, such as ruptures of the ligaments or of the semilunar cartilages.

Several methods of treatment are available. At times, treatment of the primary lesion without attention to the chondromalacia, may be adequate. For example recurrent dislocation of the patella with a valgus quadriceps mechanism may require only transplantation of the tibial tubercle and realignment of the quadriceps mechanism thereby permitting the patella to work backward and forward properly in the intercondylar notch of the femur If, during exploration of the knee for other lesions such as rupture of the semilunar cartilage, small localized areas of chondromalacia or degeneration of the patella are found, surgery should be kept to a minimum In such cases, treatment consists solely of removal of the loose fragments of cartilage and trimming of the rough irregular edges of the crater The tips of cartilage should be removed with scissors or a knife rather than with a curette The small craters may be expected to fill with fibrocartilage and cause little subsequent trouble



Fig 613.—Gross specimen following patellectomy Etiology of chondromalacia undetermined. Female, 23 years of age, housewife, history not significant.

As pointed out by Soto-Hall when the degeneration of the articular surface of the patella is extensive, involving practically the entire surface, there is only one satisfactory surgical answer total patellectomy In those cases where the total resection of the articular surface was tried, and the cancellous bone was covered with fascia or a portion of the fat pad, the results were poor

Technic (Soto-Hall).—The patella is approached through a cup-shaped incision and the quadriceps expansion is incised in the same manner the incision passing over the level of the inferior third of the patella and thereby bringing the suture line of the tendon in the area of the fat pad, rather than in the line of the femoral condyle The tendon is carefully removed from the patella by meticulous sharp dissection. Removal of the patella produces a relative lengthening of the tendon. To restore proper tension, the edges of the tendon are overlapped approximately one-half inch Soto-Hall believes that complete active extension will thus be regained more rapidly following the operation. The

medial arm of the incision may be extended somewhat higher, by so doing a V-shaped section of the capsule may be removed and plicated, restoring balance between the vasti muscles. This latter procedure is reserved for those cases wherein the valgus quadriceps mechanism is present, the lateral instability of the patella having been demonstrated before operation

After Treatment —General quadriceps contractions which have been practiced preoperatively are resumed on the third or fourth day Resistance exercises are begun after two weeks, resistance in the last fifteen or twenty degrees of extension being particularly important

Technic (Boyd) —See p 851

INTRAPELVIC PROTRUSION OF THE ACETABULUM

(Otto Pelvis—Arthrokatadysis)

The condition is characterized by a chronic progressive protrusion of the acetabulum and head of the femur into the pelvis Approximately two-thirds of these lesions are unilateral They are encountered most often in middle-aged individuals, though they may develop during adolescence

The protrusion is accompanied by pain and limited motion In severe bilateral lesions, motion may be so limited that only tripod walking is possible in the earlier stages, abduction and rotation, particularly are restricted by impingement of the trochanters against the pelvis.

In view of the progressive nature of the deformity the extreme depth of the acetabulum and the subsequent blocking of motion by the femur against the ilium and ischium arthroplasty may not be applicable. In early bilateral lesions, with minimal protrusion, mold arthroplasty is well worthy of trial a substantial segment of the anterior superior portion of the acetabulum must be excised. In severe unilateral lesions arthrodesis may be the only surgical measure of benefit.

References

Surgery of Arthritis

Allison, N., and Coonse, G K. Synovectomy in Chronic Arthritis, Arch. Surg 18 824, 1929
Berkheiser E. J: Excision of the Patella in Arthritis of the Knee Joint J A. M. A. 113 2303 1939
Bronitsky Jacob Chondromalacia Patellae J Bone & Joint Surg. 29 931 1947
Boon Itt, S. B.: A Study of the End Results of Synovectomy of the Knee J Bone & Joint Surg 12 853, 1930.
Boyd H. B., and Hawkins B L.: Patellectomy; A Simplified Technique Surg., Gynec. & Obst. 86 357 1948.
Bruce, John and Walmsley Robert: Excision of the Patella. Some Experimental and Anatomical Observations, J Bone & Joint Surg 24 311 1942
Burns, B H.: Fixation of the Osteo-Arthritic Hip by Nailing Lancet 1 978, 1939
Campbell, Willis C. Surgery as an Adjunct to the Treatment of Arthritis, Radiology 24 393, 1935.
Campbell, W C., and Smith H. Dean Lewis Practice of Surgery Hagerstown Md., 1940 W F Prior & Co
Dickson, J A., and Willien, L. J Arthrodesis of the Hip Joint in Degenerative Arthritis. A Modified One-Stage Procedure With Internal Fixation, J Bone & Joint Surg 29 687, 1947
Fisher A. G Timbrell The Principles of Orthopaedic and Surgical Treatment in the Rheumatoid Type of Arthritis, J Bone & Joint Surg 19 657 1037
Groves, E. W Hey: Some Contributions to the Reconstructive Surgery of the Hip Brit. J Surg 14 486, 1926-27
—: Surgical Treatment of Osteo-Arthritis of the Hip, Brit. M. J 1 3 1933
Haggart, G E. Degenerative Arthritis of the Hip Joint Treated by One or Two-Stage Arthrodesis With Metal Fixation (Watson Jones) J A. M. A. 128: 502, 1945.
Heyman C. H.: Synovectomy of the Knee Joint, Surg., Gynec. & Obst. 46 127, 1928.
Hoffman, Phil: An Operation for Severe Grades of Contracted or Clawed Toes, Am. J Orth. Surg 9 441, 1911 12.

Inge G A. L. Eighty Six Cases of Chronic Synovitis of Knee Joint Treated by Synovectomy J A. M. A. 111 2451 1938
Jones, Sir Robert, and Lovett, Robert W : Orthopedic Surgery New York, 1924, William Wood & Co. p 100
Jones Ellis: Synovectomy of the Knee Joint in Chronic Arthritis, J A M A. 81 1579 1923.
King T : The Value of Femoral Osteotomy for Diseases and Injuries of the Hip Joint M. J Australia 1 233 1940 (Abstracted in Arch Surg 42 108 1941)
McMurray T P Osteo-Arthritis of the Hip-Joint, British J Surg 22 716 1935.
McMurray T P A Practice of Orthopedic Surgery, Baltimore 1943, Williams & Wilkins Co.
Magnuson P B : Joint Debridement Surgical Treatment of Degenerative Arthritis, Surg., Gynec. & Obst 73 1 1941
Magnuson, P B.: Technic of Débridement of the Knee Joint for Arthritis S. Clin. North America 26 249, 1946.
Murphy, John B Cheilotomy Surg Clin John B. Murphy Vol. 4 Philadelphia, W B. Saunders Co., 1915 p. 240
Neibauer, J J., and King D : Arthrodesis of the Hip Produced by Internal Fixation, J Bone & Joint Surg 28 103, 1946.
Schumm H. C.: Trochanteric Osteotomy Indications and Technic, Lectures on Peace and War Orthopaedic Surgery Am. Acad Surg. Year Book, Ann. Arbor Michigan, 1943, J W Edwards.
Shands, A. R., Jr., and Oates, M. O : Atrophic and Hypertrophic Arthritis of the Spine, South. M. J 26 384 1933.
Smith Petersen, M. N Treatment of Malum Coxae Senilis, Old Slipped Upper Femoral Epiphysis, Intrapelvic Protrusion of the Acetabulum, and Coxa Plana by Means of Acetabuloplasty J Bone & Joint Surg 18 869, 1936.
Smith Petersen M. N A New Approach to the Wrist Joint, J Bone & Joint Surg. 22 122, 1940
Smith Petersen M. N., Aufranc, O E., and Larson, C. B. Useful Surgical Procedures for Rheumatoid Arthritis Involving Joints of the Upper Extremity Arch. Surg 46 764 1943
Soto Hall, R Traumatic Degeneration of the Articular Cartilage of the Patella, J Bone & Joint Surg. 27 426, 1945
Speed J S.: Synovectomy of the Knee Joint, J A. M. A. 83 1814 1924.
Stuck, W G., and Hinchey J J Experimentally Increased Blood Supply to the Head and Neck of the Femur Surg., Gynec. & Obst 78 160 1944.
Swett P P Present Status of Synovectomy Am. J Surg 6 807, 1929
— Synovectomy in Chronic Infectious Arthritis, J Bone & Joint Surg 5 110 1923.
— A Review of Synovectomy J Bone & Joint Surg 20 68, 1938.
Watson Jones, Reginald Fractures and Joint Injuries, ed. 3, Baltimore, 1946, Williams & Wilkins Co
Watson-Jones R. Arthrodesis of the Osteoarthritic Hip J A. M. A. 110 278 1938.
White, J W : Smith Petersen Nail Fixation in Hip Disease, South. M. J 36 333 1943.
Wilson, P D Surgical Reconstruction of the Arthritic Cripple, M. Clin. North America 21 1623 1937
Wilson, P D., and Osgood, R. B Reconstructive Surgery in Chronic Arthritis, New England J Med. 209 117 1933
Young, H. H., and Regan, J M.: Total Excision of the Patella for Arthritis of the Knee, Minnesota Med. 28 909 1945

Low Back Pain—Sciatic Pain

Adson, A. W and Ott, W O Results of the Removal of Tumors of the Spinal Cord, Arch. Neurol. & Psychiat 8 520 1922.
Ayers, C. E.: Further Case Studies of Lumbo-Sacral Pathology with Consideration of the Involvement of the Intervertebral Discs and the Articular Facets, New England J Med. 213 716 1935.
—: Lumbo-Sacral Backache, New England J Med. 200: 592, 1929
Barr J S. Intervertebral Disc Lesions as a Cause of Sciatica, Brit. M. J 2 1247 1938.
Barr J S.: Ruptured Intervertebral Disc and Sciatic Pain, J Bone & Joint Surg. 29 429 1947
Barr J S., Hampton, A. O., and Mixter W J : Pain Low in the Back and Sciatica Due to Lesions of the Intervertebral Discs, J A. M. A. 109 1265 1937
Barr Joseph S. Sciatica Caused by Intervertebral Disc Lesions, J Bone & Joint Surg 19 323 1937
Brown, Lloyd T The Mechanics of the Lumbosacral and Sacro-Iliac Joints, J Bone & Joint Surg 19 770, 1937
Campbell, Willis C.: Operative Measures in the Treatment of Affections of the Lumbosacral and Sacro-Iliac Articulation, Surg., Gynec. & Obst. 51: 381 1930.

Chandler Fremont A.: Spinal Fusion Operations in the Treatment of Low Back and Sciatic Pain J A M A. 93: 1447, 1929
Compere, E. L. The Operative Treatment for Low Back Pain, J Bone & Joint Surg 19 740, 193(
Compere E. L.: Spinal Fusion Following Removal of Intervertebral Disc South. M. J 39 301 1946.
Compere E. L., and Keyes D C.: Roentgenological Studies of the Intervertebral Disc Discussion of Embryology, Anatomy, Physiology Clinical and Experimental Pathology, Am. J Roentgenol. 29 7,4 1933
Craig W McK., and Ghormley, Ralph K. The Significance and Treatment of Sciatic Pain, J A. M. A. 100 1143, 1933
Elsberg C. A.: Experiences in Spinal Surgery Observations Upon 60 Laminectomies for Spinal Disease, Surg Gynec. Obst. 16 117, 1913
Fincher, E. F Neurologic Aspects of Low Back Pain and Sciatica, Ann. Surg 109 1028 1939
Freiberg A. H Sciatic Pain—Its Clinical Significance, Ohio State M J 30 21, 1934.
Freiberg A H., and Vinke, T H. Sciatica and the Sacro-Iliac Joint, J Bone & Joint Surg 16 126 1934.
Goldthwait, J E.: Backache New England J Med. 209 722, 1933
— Low Back Lesions, J Bone & Joint Surg 19 810, 1937
Haggart, G E. Discussion of Spurling et al. J A. M A. 109 9?8, 1937
— Sciatic Pain of Unknown Origin. An Effective Method of Treatment, J Bone & Joint Surg 20 851 1938.
Josey A. I., and Murphey F Ruptured Intervertebral Disc Simulating Angina Pectoris, J A. M. A. 131 581 1946
Keegan, J J Dermatome Hypalgesia Associated With Herniation of Intervertebral Disc, Arch. Neurol. & Psychiat. 50 67, 1943
Keyes, D C., and Compere, E. L. The Normal and Pathological Physiology of the Nucleus Pulposus of the Intervertebral Disc. An Anatomical, Clinical, and Experimental Study J Bone & Joint Surg 14 897 1932.
Lenhard, R. E. End Result Study of the Intervertebral Disc, J Bone & Joint Surg 29 425 1947
Love, J G The Disc Factor in Low Back Pain With or Without Sciatica, J Bone & Joint Surg 29 438 1947
Love J G Special Nerve Root Retractor Used in Removing Protruded Intervertebral Discs Proc. Staff Meet., Mayo Clin. 12 393 193
Love J G: Removal of Protruded Intervertebral Discs Without Laminectomy Proc. Staff Meet., Mayo Clin. 14 800 1939 Correction 15 4 1940.
Love J G., and Camp J D Root Pain Resulting from Intraspinal Protrusion of Intervertebral Discs. Diagnosis and Surgical Treatment, J Bone & Joint Surg 19 776, 1937
Mercer Walter Orthopaedic Surgery Baltimore, 1936, William Wood & Co., Chap. 15, pp 586 and 803.
Meyerding H. W Low Backache and Sciatic Pain, Associated With Spondylolisthesis and Protruded Intervertebral Disc Incidence Significance and Treatment (Symposium), J Bone & Joint Surg 23 461 1941
Mitchell, C. L. Lumbosacral Facetectomy for Relief of Sciatic Pain a Case Report, J Bone & Joint Surg. 16 706, 1934.
Mixter W J., and Ayer, J B.: Herniation or Rupture of the Intervertebral Disc Into the Spinal Canal. Report of Thirty Four Cases, New England J Med. 213 385, 1935
Mixter W J., and Barr J S. Rupture of the Intervertebral Disc With Involvement of the Spinal Canal, New England J Med. 211 210 1934.
Mixter W J., and Barr Joseph S. Rupture of the Intervertebral Disc with Involvement of the Spinal Canal, New England J Med. 211 210 1934
Murphey, F., Pascucci, L. M., Meade W H., and Van Zwaluwenburg B. R.: Myelography in Patients With Ruptured Cervical Intervertebral Discs Am. J Roentgenol. 56 27, 1946.
Naffziger, H. C., Inman, V., and Saunders, J B. deC. M. Lesions of the Intervertebral Disc and Ligamenta Flava Clinical and Anatomical Studies Surg., Gynec. & Obst. 66 ?88 1938.
Oppenheimer A., and Turner E. L. Discogenetic Disease of the Cervical Spine With Segmental Neuritis, Am. J Roentgenol. 37 484, 193(
Osgood R. B.: Etiologic Factors in Certain Cases of So-Called Sciatic Scoliosis, J Bone & Joint Surg 9 667, 1927
Peet M. M., and Echols, D H. Herniation of the Nucleus Pulposus Cause of Compression of Spinal Cord, Arch. Neurol. & Psychiat. 32 924, 1934
Putti, V: New Conceptions in the Pathogenesis of Sciatic Pain, Lancet 2 53 1927
— Sciatica: Its Cause and Treatment, Brit. M. J 1 522, 1927
Roofe P G: Innervation of Annulus Fibrosis and Posterior Longitudinal Ligament Fourth and Fifth Lumbar Level, Arch. Neurol. & Psychiat 44: 100 1940.

Ryerson Edwin W Surgical Treatment of Low Back Disabilities, J Bone & Joint Surg. 14: 154 1932.
Schmorl G., and Junghanns, H. Archiv und Atlas der Normalen und Pathologischen Anatomie in Typischen Röntgenbildern, Leipzig 1932, Georg Thieme.
Scoville W B.: Personal communication, 1947
Semmes, R. E. Diagnosis of Ruptured Intervertebral Disc Without Contrast Myelography and Comment upon Recent Experience with Modified Hemilaminectomy for their Removal, Yale J Biol. & Med. 11 433 1939
Semmes, R. E., and Murphey F The Syndrome of Unilateral Rupture of the Sixth Cervical Intervertebral Disc, With Compression of Seventh Cervical Root Report of Four Cases With Symptoms Simulating Coronary Disease, J A. M. A. 121 1209 1943
Spurling R. G., and Bradford, F K. Neurologic Aspects of Herniated Nucleus Pulposus at the Fourth and Fifth Lumbar Interspaces, J A. M. A. 113 2019 1939
Spurling R. G., and Grantham, E. G Neurologic Picture of Herniations of the Nucleus Pulposus in the Lower Part of the Lumbar Region Arch. Surg 40: 375 1940.
Spurling R G., Mayfield F H., and Rogers, J B Hypertrophy of the Ligamenta Flava as a Cause of Low Back Pain, J A. M. A. 109 928, 1937
Spurling R. G., and Scoville, W B.: Lateral Rupture of the Cervical Intervertebral Discs A Common Cause of Shoulder and Arm Pain, Surg., Gynec. & Obst. 78 350 1944.
Steindler A. Differential Diagnosis of Pain Low in the Back, J A. M. A. 110 106, 1938
—: Diseases and Deformities of the Spine and Thorax, St. Louis, 1929 C. V Mosby Co.
Stookey, B Compression of the Spinal Cord Due to Ventral Extradural Cervical Chondromas Diagnosis and Surgical Treatment, Arch. Neurol. & Psychiat. 20 275 1928.
Stookey, B.: Compression of Spinal Cord and Nerve Roots by Herniation of the Nucleus Pulposus in the Cervical Region, Arch. Surg 40 417 1940.
Williams, P C.: Reduced Lumbosacral Joint Space Its Relation to Sciatic Irritation, J A. M. A. 99 1677, 1932.
Williams, P C. Lesions of the Lumbosacral Spine, Acute Traumatic Destruction of Lumbosacral Intervertebral Disc, J Bone & Joint Surg. 19 343, 1937
Willis, T A. An Analysis of Vertebral Anomalies, Am. J Surg. 6: 163 1929
—: *Low Back Pain. The Anatomical Structure of the Lumbar Region Including Variations* J Bone & Joint Surg 19 745 193

Charcot s Joints—Syphilis—Parasyphilitic Arthropathies

Campbell, Willis C.: An Analysis of Bone and Joint Lesions of Known Syphilitic Origin, Radiology 5 122, 1923.
Cleveland Mather and Smith, Alan DeF Fusion of the Knee Joint in Cases of Charcot s Disease. Report of Four Cases, J Bone & Joint Surg 13 849 1931.
Key J A. The Treatment of Tabetic Arthropathies (Charcot s Joints) Urol. & Cutan. Rev 49 161 1945.
Shands, A. R., Jr: Neuropathies of the Bones and Joints: Report of a Case of an Arthropathy of the Ankle Due to a Peripheral Nerve Lesion, Arch. Surg 20 614 1930
Soto Hall R. Fusion in Charcot s Disease of the Knee New Technic for Arthrodesis, Ann. Surg. 108 124 1938
Steindler A. The Tabetic Arthropathies, J A. M. A. 96 250 1931

Epiphysitis—Osteochondritis

Bosworth, D M.: Autogenous Bone Pegging for Epiphysitis of the Tibial Tubercle, J Bone & Joint Surg 16 829 1934.
Bozsan, E. J: A New Treatment of Intracapsular Fractures of the Neck of the Femur and Calvé-Legg Perthes Disease J Bone & Joint Surg 14: 884 1932.
Campbell, Willis C. Infraction of the Head of the Second and Third Metatarsal Bones. Report of Cases, Am. J Orthop. Surg 15: 721, 1917
Danforth, M. S. The Treatment of Legg-Calvé-Perthes Disease Without Weight Bearing, J Bone & Joint Surg 16 516, 1934
Ferguson, A. B., and Howorth, M. B.: Coxa Plana and Related Conditions at the Hip, J Bone & Joint Surg 16 781 1934
Freiberg, A. H.: Infraction of the Second Metatarsal Bone. A Typical Injury Surg. Gynec Obst. 19 191, 1914.
Groves, E. W Hey: Some Contributions to the Reconstructive Surgery of the Hip, Brit. J Surg. 14 486, 1926-27
Karp, M. G Köhler s Disease of the Tarsal Scaphoid, J Bone & Joint Surg. 19 84, 1937
Key J A. Epiphyseal Coxa Vara or Displacement of the Capital Epiphysis of the Femur in Adolescence, J Bone & Joint Surg. 8 53 1926.
Köhler A.: Typical Disease of the Second Metatarso-Phalangeal Joint, Am. J Roentgenol 10 705 1923.

— Ueber eine häufige bisher anscheinend unbekannte Erkrankung einzelner kindlicher Knochen, München. med. Wchnschr 45: 1923, 1908.
Mitchell Jos. I: Vertebral Osteochondritis, Arch Surg 25 514 1932.
Mouchet, Albert Metatarsal Epiphysitis J Bone & Joint Surg 11 87, 1929

Slipped Upper Femoral Epiphysis

Badgley, C. E.: Displacement of the Upper Femoral Epiphysis, Summary of 27 Studied Cases, J A. M. A. 92 333, 1929
Badgley C E., Isaacson A S., Wolgamot J C, and Miller J W: Operative Therapy for Slipped Upper Femoral Epiphysis. An End Result Study, J Bone & Joint Surg 30-A 19, 1948
Ferguson, A. B., and Howorth, M. B. Slipping of Upper Femoral Epiphysis A Study of Seventy Cases, J A M. A 97 1867 1931
Forrester Brown, M. Slipping of the Upper Femoral Epiphysis End Result After Conservative Treatment J Bone & Joint Surg 23: 256 1941
Ghormley, R. K., and Fairchild R. D: Diagnosis and Treatment of Slipped Epiphysis, J A. M A. 114 229, 1940.
Green, W T: Slipping of the Upper Femoral Epiphysis; Diagnostic and Therapeutic Considerations, Arch. Surg 50 19 1945
Haas, Sylvan L.: Lengthening of the Femur With Simultaneous Correction of Coxa Vara J Bone & Joint Surg 15 219, 1933.
Hark, F W: Treatment of Separation of Upper Femoral Epiphysis, S. Clin. North America 22 119 1942.
Howorth, M. B. Slipping of Upper Femoral Epiphysis, Surg Gynec. & Obst. 73 723, 1941
Jahss, S. A. Slipping of the Upper Femoral Epiphysis, J Bone & Joint Surg 15 477 1933
Key J A. Epiphyseal Coxa Vara or Displacement of the Capital Epiphysis of the Femur in Adolescence J Bone & Joint Surg 8 53, 1926.
Klein A., Joplin, R. J., and Reidy, J A. Treatment in Cases of Slipped Capital Femoral Epiphysis at Massachusetts General Hospital, Arch. Surg 46 681, 1943
Kleinberg S., and Buchanan, J: The Operative Versus the Manipulative Treatment of Slipped Femoral Epiphysis, J A. M. A. 107 1545 1936.
MacAusland, A. R. Separation of the Capital Femoral Epiphysis, J Bone & Joint Surg 17 853, 1935.
Martin, P H. Slipped Epiphysis in the Adolescent Hip A Reconsideration of Open Reduction, J Bone & Joint Surg. 30-A: 9, 1948.
Mayer Leo The Importance of Early Diagnosis in the Treatment of Slipping Femoral Epiphysis, J Bone & Joint Surg 19 1046 1937
Moore, R. D: Aseptic Necrosis of the Capital Femoral Epiphysis Following Adolescence Epiphyseolysis, Surg., Gynec. & Obst. 80 199, 1945.
Pomeranz, M. M., and Sloane M F Slipping of the Proximal Femoral Epiphysis. Therapeutic Results of 101 Cases, Arch. Surg 30 607 1935
Sever J W Slipping Epiphysis of the Head of the Femur New England J Med. 211 1179 1934.
Waldenström, H. Slipping of Upper Femoral Epiphysis, Surg Gynec. & Obst 71 198 1940
West, W K. Treatment of Slipped Upper Femoral Epiphyses, South. M. J 35 1082, 1942.
Wilson, P D Displacement of Upper Epiphysis or Femur Treated by Open Reduction J A. M. A. 83 1749 1924.
Wilson P D: Conclusions Regarding the Treatment of Slipping of the Upper Femoral Epiphysis, Surg Clin. of North America 16 733 1936
— The Treatment of Slipping of the Upper Femoral Epiphysis With Minimal Displacement, J Bone & Joint Surg 20 379 1938
—: Displacement of Upper Epiphysis of Femur Treated by Open Reduction, J A M A. 83 1749 1924

Miscellaneous

Linton, R. R., and Talbott, J H. Surgical Treatment of Tophaceous Gout Ann. Surg 117 161, 1943
Pomeranz, M. M. Intrapelvic Protrusion of the Acetabulum (Otto Pelvis) J Bone & Joint Surg 14 663 1932.

CHAPTER XIV

TUBERCULOSIS

Tuberculosis of the joints is a destructive disease induced by the tubercle bacillus. Since the lesion is always secondary to a tuberculous focus elsewhere in the body the patient should be given a general physical examination in an endeavor to discover the focus. Roentgenograms of the lungs should be made routinely as an active pulmonary tuberculosis may be associated. A pulmonary lesion if present, adds materially to the gravity of the prognosis and consequently should receive due consideration in the treatment

Because of the relation between the primary visceral focus and that of tuberculosis *of the joints, systemic treatment to build up the patient's resistance* is of utmost importance. This treatment should consist of proper hygienic surroundings, a well balanced diet, fresh air heliotherapy and other measures. The efficacy of streptomycin or other antibiotics is yet to be proved prospects of help from this source are encouraging The use of streptomycin preoperatively and postoperatively in connection with fusion has apparently reduced some of the complications, such as persistent draining sinuses However the benefits of streptomycin are limited in the same way that penicillin is limited in the treatment of chronic osteomyelitis, viz., in avascular scarred areas the antibiotic does not get to the center of the focus.

Operative measures applicable to tuberculous lesions of joints may be enumerated as follows (1) excision of bones, (2) excision of joints, (3) amputation, (4) fusion, and (5) surgical treatment of complications (abscess and paraplegia)

EXCISION OF BONES

Complete excision or curettage of an early tuberculous focus in a long bone prior to invasion of a joint is theoretically possible but seldom successful The ultimate results in a large number of cases will prove the fallacy of such a procedure. Operations of this type have been reported for removal of tuberculous foci in the condyles of the tibia, surgical neck of the humerus, *and greater trochanter of the femur In a few cases, we have resected* small destructive areas in the neck of the femur adjacent to the epiphysis, which were shown to be tuberculous on microscopic section The infection was apparently quiescent for a few months after operation but was then disseminated more rapidly throughout the hip joint. In most instances this measure is not practicable

All authors, however are not in accord as to the efficacy of early excision of a tuberculous focus. Erlacher for example believes that, since tuberculosis of the bones almost always begins in a small, circumscribed area, radical excision should be carried out in the initial stages that early extirpation of the focus gives results obtainable by no other method of treatment, leading to rapid healing of the local lesion and often preservation of normal motion. The operation may consist of simple removal of the diseased, discolored, or softened tissue from the bone or capsule with an electric cautery or extensive eradication. In adults, Erlacher regards resection as justifiable in late stages of the disease. He practically condemns arthrodesis as being fundamentally unsatisfactory in that fusion does not eliminate the focus.

If a bone or bones can be removed in toto without producing excessive deformity and disability, excision may be a curative measure This procedure is limited almost entirely to the bones of the foot and wrist. Segments of certain long bones, such as the head of the radius, distal end of the ulna, and upper two-thirds of the fibula may likewise be excised (see excision of bone tumors and excision for osteomyelitis)

EXCISION OF BONES OF THE FOOT

If the tuberculous process is in an early stage and is confined to a single bone excision may be followed within a few months by primary healing of the wound If the disease is far advanced with draining sinuses and secondary infection, drainage may persist for a longer period, although the final result may be excellent

In adults, should several bones of the foot be involved, amputation is often the procedure of choice, extensive excisions, even though the disease is eradicated, may leave a deformed and worthless extremity According to Miltner and Fang in multiple infections the most important weight bearing bones are affected, the order of incidence being, from the highest to the lowest, as follows os calcis, astragalus, first metatarsal scaphoid, and first and second cuneiform bones.

Curettage is practically valueless. The infected area must be excised en masse, if possible, to prevent dissemination of the disease process. If destruction is extensive, removal of the bone piece by piece may be necessary

Reconstructive measures are undertaken in conjunction with excision of a tarsal bone in order to restore proper mechanics and provide a stable painless weight bearing foot for example if a midtarsal bone is excised, a proportionate amount of normal bone is taken from the opposite side of the foot to permit proper alignment.

Excision of a Metatarsal Bone

When the second, third, or fourth metatarsal bone is completely excised amputation of the corresponding toe may permit better approximation of the adjacent metatarsals and produce a foot of more normal appearance. To obliterate the space thus created, the adjacent metatarsal bones are divided at their bases by osteotomy and shifted laterally or medially as necessary This procedure is postponed, however if tuberculosis is complicated by secondary infection as the normal bone may subsequently become infected Instead, osteotomy is carried out after the wound has healed, which may require several months. Excision of the first metatarsal bone obviously causes considerable disability since an important portion of the weight bearing surface of the *forefoot* is removed.

Technic.—A longitudinal incision is made over the affected bone parallel with the long axis, extending from the distal row of tarsal bones to the middle of the proximal phalanx. The superficial and deep fasciae are incised between the tendons the sheaths are not opened Dissection is carried down to the periosteum, the tarsometatarsal and metatarsophalangeal joints are exposed and the bone is completely resected, with the periosteum intact if possible

If the second third fourth or fifth metatarsals are involved the corresponding toe is amputated through a continuation of the longitudinal incision around its base. By osteotomy of the adjacent metatarsal bones at their

proximal extremities one-fourth inch distal to the tarsometatarsal joints, each bone may be shifted to obliterate the intervening space. This produces a rather narrow foot but one which will afford better function with a more normal appearance When the second metatarsal is excised, the space created should be obliterated by shifting the outer three metatarsals, leaving the first undisturbed

After Treatment.—The foot is immobilized in a closely fitting cast from the toes to the upper third of the leg A large window is cut over the dorsum of the foot, then replaced and held in position with a bandage. At the end of three weeks, if the wound has healed a walking cast is applied and weight bearing instituted Eight weeks following operation a steel arch support is fitted into an orthopedic shoe and walking is resumed with shoe and support

The results of this procedure usually are excellent, seldom is there subsequent infection if the diseased area is completely excised.

Excision of the Cuneiform Bones

When the disease process is limited to one or more cuneiform bones, excision gives an excellent functional result, as motion in the midtarsal joints is preserved Usually more than one of the bones are involved, necessitating an anterior tarsectomy To obtain a satisfactory alignment of the foot, a portion of the cuboid bone must also be removed.

Technic.—A two inch lateral incision is made in the longitudinal axis of the foot, exposing the articulation between the cuboid and proximal end of *the fifth metatarsal bone The first cuneiform and the base of the first* metatarsal bone are approached through a similar medial incision. The middle cuneiforms are exposed by subperiosteal dissection. With an osteotome, a section of bone consisting of the anterior half of the cuboid and the three cuneiforms is removed. The articular cartilage is resected from the anterior articular surface of the scaphoid and the bases of the proximal portions of all five metatarsal bones. The roughened cancellous surfaces of the metatarsal bones are then approximated to the scaphoid and cuboid, to produce a firm union between these structures.

After Treatment.—See p. 911.

Excision of the Scaphoid Bone

As function of the midtarsus is untenable following excision of the scaphoid alone, a midtarsal arthrodesis should be performed to stabilize the foot in satisfactory alignment

Technic.—The midtarsus is exposed by an anterolateral incision (p 137) For a more complete view an additional incision two inches in length may be made over the medial aspect of the scaphoid. The capsules of the astragaloscaphoid and the scaphocuneiform joints are opened, and the scaphoid is grasped with rat tooth Ochsner forceps and excised by severance of all ligamentous attachments. If no medial incision is made, the attachment to the capsule on the inner aspect must be severed with curved scissors. Care must be taken to avoid injury to the dorsalis pedis artery and the terminal branches of the deep peroneal nerve on the dorsum of the foot dissection close to the bone *should obviate this danger*

Through the same incision, the calcaneocuboid joint is exposed below and to the lateral aspect on a plane with the head of the astragalus. The articular cartilage and superficial bone are excised from the anterior extremity of

the os calcis and the posterior two thirds of the cuboid bone The articular cartilage of the head of the astragalus and posterior surfaces of the internal cuneiform bones is likewise removed to cancellous tissue The raw surfaces of the cuboid and os calcis, and the astragalus and cuneiform bones are ap proximated, thus obliterating the space and permitting osseous union This position may be maintained more accurately by a chromic catgut suture passed through a drill hole in the cuboid and os calcis.

After Treatment.—With the foot in correct alignment, a boot cast is applied and a window is cut out over the dorsum of the foot to allow for swelling After four weeks, the cast is removed and any slight malalignment is cor rected If the wound has healed the foot is placed in a walking boot cast and walking permitted The cast should be retained for a period of four to eight weeks a free motion ankle brace is then applied the joint being held rigid during the first month of weight bearing At the end of six months the brace may discarded.

Should drainage be present when the first cast is removed bed rest should again be enforced and immobilization continued by another cast until only a small amount of drainage persists. The after treatment is then carried out as described above. Drainage may persist for an indefinite period in the presence of secondary infection.

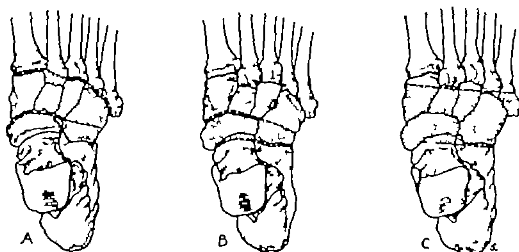


Fig. 614.—*A* Resection of cuneiform bones. *B* Resection of scaphoid bone. *C* Resection of cuboid bone. *Shaded areas represent bone removed for proper alignment of foot.*

Excision of the Cuboid Bone

Technic.—The cuboid bone is approached through an anterolateral in cision and excised in toto following separation of all ligamentous attachments The articular surfaces of the posterior aspect of the cuneiforms and the fifth metatarsal bones, and the anterior surface of the os calcis are then resected with the adjacent superficial bone. The entire scaphoid and the articular cartilage and superficial bone from the head of the astragalus are also re moved. The osseous surfaces of the cuneiforms and fifth metatarsal bones are approximated to the astragalus and os calcis and so maintained by No 1 chromic catgut sutures inserted through the remaining portions of the cap sules or the sutures may be placed through holes in the bones on each side The Lewin clamp may be used for making the holes

After Treatment.—See above.

Excision of the Os Calcis

Disability is so extreme following resection of the os calcis that the operation is rarely employed Amputation through the middle and upper thirds of the leg and the use of an artificial limb are as a rule, preferable. There may, however, be some difference of opinion on this subject

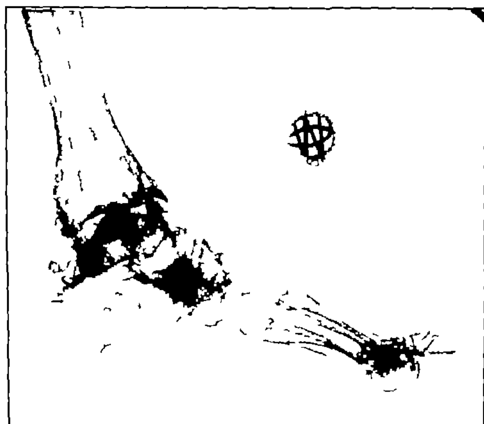


Fig. 615.—Resection of midtarsus for tuberculosis, anterior and posterior extra-articular fusion of ankle joint.

Gaenslen reports two cases of tuberculosis of the os calcis wherein he employed a technic similar to that which he described for surgical treatment of osteomyelitis of the os calcis (p 1136) In one of his cases, healing followed, with an excellent result sinuses persisted indefinitely in the other Pouzet has treated twenty four children with tuberculosis of the os calcis. In twenty three of these, the lateral surface of the os calcis was exposed through an L-shaped incision and a thorough curettage was performed. Only a shell of bone was left Sixteen patients so treated recovered completely and obtained a good functional and anatomic result. Possibly either the Gaenslen or Pouzet technic should be given a trial prior to amputation or excision, provided the disease is in the incipient stage and is confined to the one bone.

Technic.—A Kocher incision is made, beginning four inches above the external malleolus, following roughly the lateral border of the tendo achillis to the superior surface of the os calcis, and extending below the external malleolus to one inch anterior to the calcaneocuboid joint. The external lateral ligament of the ankle joint is incised and the peroneal tendons displaced upward and anteriorly After incision of the capsule and severance of the ligamentous attachments of the os calcis at the calcaneocuboid joint, a periosteal elevator is inserted into the subastragalar joint and, by leverage,

the joint surfaces are separated sufficiently to provide adequate exposure of the ligaments of the sinus tarsi and other ligaments between the astragalus and os calcis. The soft tissue attachments are severed from before backward until the os calcis can be dislocated completely at the subastragalar joint. By sharp dissection close to the bone, soft tissue attachments on the medial, anterior, and posterior surfaces, including the attachment of the tendo achillis, are freed and the os calcis is removed Care must be taken to protect the tibial nerve and vessels during subperiosteal separation of the ligaments on the medial aspect The tendo achillis is sutured to the inferior surface of the astragalus, and to the short muscles of the foot.

After Treatment.—This is identical with the after treatment of excision of the astragalus. The walking boot cast must be well fitted to compensate for loss of the os calcis. An arch support with the heel elevated by several layers of sponge rubber will facilitate walking

Excision of the Astragalus

The astragalus is affected by tuberculosis more often than any other bone of the foot with the exception of the os calcis. Frequently, the following procedure will afford a satisfactory weight bearing foot.



Fig. 616.—Tuberculosis of astragalus. Disease eradicated and a stable, painless weight bearing foot re-established by astragalectomy

Technic.—The Kocher approach (p 138) or the anterolateral approach (p 137) provides adequate exposure

The ankle, subastragalar and astragaloscaphoid joints are exposed through an anterolateral incision which begins two inches above the ankle and extends one inch beyond the calcaneocuboid joint. The capsule and ligamentous attachments of the astragaloscaphoid joint are severed on the dorsal, lateral, and inferior aspects. After division of the external lateral ligament at its attachment to the external malleolus, the astragalus, with the entire foot, may be dislocated at the ankle joint and displaced medially thus bringing into view the articular and medial surfaces of the astragalus The neck of the astragalus is grasped with Ochsner forceps and slight traction is exerted By sharp dissection close to the bone all soft tissues and ligamentous attachments on the inferior and posterior aspects are severed from before backward

and the astragalus is removed No important structures should be disturbed by this method In the presence of extensive necrosis, the bone must be excised in pieces.

The soft tissues on both malleoli and both sides of the anterior aspect of the os calcis are freed by subperiosteal dissection By this procedure, the entire foot may be displaced backward and the anterior aspect of the os calcis inserted between the malleoli, the superior aspect of the os calcis, with its two articular surfaces, should closely approximate the articular surface of the tibia. The wound is closed in layers while the foot is held in moderate equinus In this position, better approximation is secured and dead space is obliterated

After Treatment —The foot is maintained in moderate equinus by a cast extending from the toes to the upper third of the thigh with the knee at 150 degrees. A window should be cut over the dorsum of the foot and ankle and loosely replaced

The cast is removed at the end of two weeks and if the wound is satisfactorily healed the sutures are also removed A new cast is applied extending to the knee still maintaining the foot in equinus. At the end of eight weeks, a walking boot cast is applied the foot being held in the same position and weight bearing is gradually resumed At the end of four months following operation a leather corset with steel reinforcements on each side is fitted, holding the foot in moderate equinus or a steel brace may be used, with a steel insole plate to hold the foot in this position. The corset or brace fits into the shoe and the heel of the shoe is elevated After six months, this support is discarded although the elevation on the heel should be retained for several additional months.

EXCISION OF JOINTS

Excision of joints as a treatment for tuberculosis was at one time widely advocated but except for lesions of the elbow possibly the wrist in some cases, and rarely the hip is now practically obsolete. The disease usually cannot be entirely removed and a more virulent process is often incited. In children, excision should be especially avoided since the epiphyses are seriously damaged resulting in a material decrease in length of the member when full growth is attained Excision of the knee joint is still discussed in modern textbooks on general surgery although almost wholly abandoned by orthopedic surgeons.

Synovectomy first performed by Volkmann in 1877 for the treatment of tuberculosis of the knee, has also fallen into disuse Since tuberculosis of the knee is seldom confined to the synovium there is grave danger of instigating a more active disease by this procedure alone. (Campbell however has performed synovectomy with a successful outcome in two cases wherein the process was believed to be low-grade arthritis but later was proved by microscopic examination to be tuberculosis.) Synovectomy may be employed as a supplement to fusion when incision into the joint reveals caseous material with disintegrating cartilage and bone, suggesting tuberculosis.

Fusion, which will be described later has almost supplanted the operation of excision for tuberculosis of the joints.

EXCISION OF THE HIP JOINT

This operation should be undertaken only in adults with extensive destruction of the head and neck of the femur and the ilium complicated by secondary infection and sepsis, and then not until all other measures have failed. The procedure is a serious one, and the patient should have a thorough preoperative preparation, including multiple transfusions

Technic.—The lateral U or other lateral incisions (p 147) may be employed. The posterior Kocher incision provides excellent dependent drainage but does not afford adequate exposure. Campbell prefers the anterior iliofemoral incision (p 146) The capsule is opened the head and neck of the femur are excised, all necrotic and pathologic tissue is removed from the acetabulum, and the trochanter is reduced into the acetabulum. In some cases, a portion of the ilium must be removed with the acetabulum A drainage tube is inserted into the lower extremity of the wound, to be removed at the end of three days.

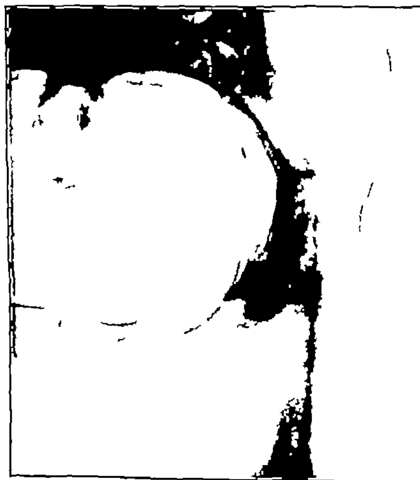


Fig. 617 —Solid ankylosis following resection of hip for associated tuberculous and pyogenic infection.

After Treatment.—A double spica cast is applied, holding the hip in 135 degrees abduction. Immobilization must be continued indefinitely

The end results of this operation are far from gratifying The general condition of the patient may be improved and the disease focus eradicated or on the other hand the infection may be exacerbated and may metastasize to distant organs, or death may ensue from sepsis or other complications. Should

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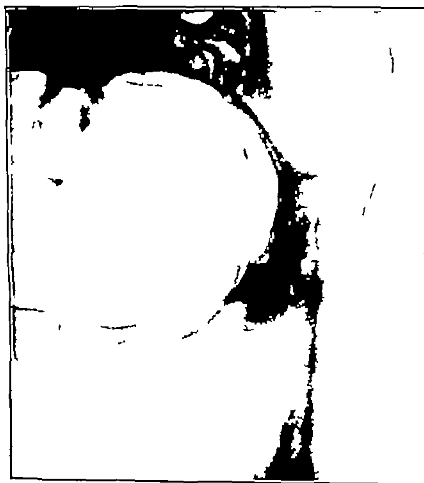


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After Treatment.—A double spica cast is applied, holding the hip in 135 degrees abduction. Immobilization must be continued indefinitely.

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healing take place, the joint will be unstable this, however may be corrected by a Schanz osteotomy (p 1617) after all evidence of the infection has subsided, or by arthrodesis.

Girdlestone has described a more extensive procedure, which may be employed instead of the true excision described above (p 211)

EXCISION OF THE ELBOW JOINT

In children excision of the elbow is not advisable, as conservative treatment affords a good prognosis. Further, excision will materially shorten the arm and consequently impair function. In adults, excision is the treatment of choice particularly when destruction is excessive. Since the elbow is a non weight bearing joint, a moderate degree of lateral instability which follows resection does not represent a serious disability A flail elbow follows only extensive resections Fusion of the elbow by surgery is obtained with difficulty and, except in the laborer produces a greater disability

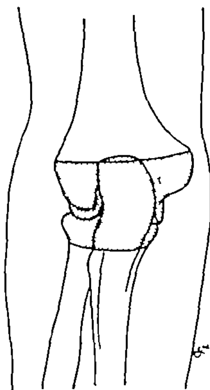


Fig 618.—Shaded area represents amount of bone ordinarily excised for tuberculosis of elbow joint.

Technic.—A longitudinal incision is made over the posterolateral aspect of the elbow, extending from four inches above to two inches below the joint (p 162) and carried through the superficial and deep fascia. The triceps muscle is incised down to the humerus, parallel with the external border of the aponeurosis. The posterior capsule of the elbow joint is opened and the incision of the deep structures continued to approximately one inch below the head of the radius. The periosteum and soft tissues are stripped from the lower extremity of the humerus with a periosteal elevator and the bone is severed just above the condyles, as much of the metaphysis as possible being left. The ulna and radius are excised, as a rule just below the level of the head

Fig. 619.—Early tuberculosis of elbow

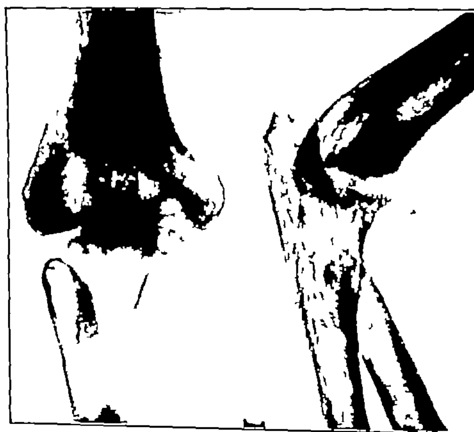


Fig. 620.—Same as Fig. 619. Following resection, disease eliminated and useful range of motion restored. Roentgenographic appearance is that of an arthroplasty; ordinarily the bone should be more extensively resected.

healing take place, the joint will be unstable this, however may be corrected by a Schanz osteotomy (p 1617) after all evidence of the infection has subsided, or by arthrodesis.

Girdlestone has described a more extensive procedure, which may be employed instead of the true excision described above (p 211)

EXCISION OF THE ELBOW JOINT

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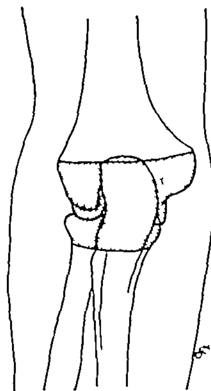


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Fig. 619 —Early tuberculosis of elbow



Fig. 620 —Same as Fig. 619 Following resection, disease eliminated and useful range of motion restored. Roentgenographic appearance is that of an arthroplasty ordinarily the bone should be more extensively resected.

of the radius more extensive excision will result in a loose, flail joint. The synovial membrane, all hypertrophied and diseased tissue, and the investing scar tissue of all sinuses are removed, and the wound is closed.

If a more extensive resection is necessary Davidson and Horwitz recommend severing the triceps from the olecranon with an osteotome, leaving a small portion of the olecranon attached to the tendon. In closing the wound, this bony fragment is apposed to the upper end of the ulna by interrupted sutures passed through a hole drilled in the ulna, and to the tendon of the triceps.

After Treatment.—The arm is maintained in a right-angle elbow splint for three to four weeks. Thereafter muscular education and active use will eventually give a serviceable, though rather unstable, member in the majority of cases.

Usually a brace is unnecessary though a sling should be worn for at least three months to prevent excess traction on the soft tissues and consequently undue lateral instability In the majority of cases, there is a permanent lateral instability of 10 to 15 degrees, this, however, is compatible with good function.

EXCISION OF THE WRIST JOINT

In the wrist the choice between fusion and excision is debatable A stiff wrist in good position may permit better endurance with excellent function of the hand

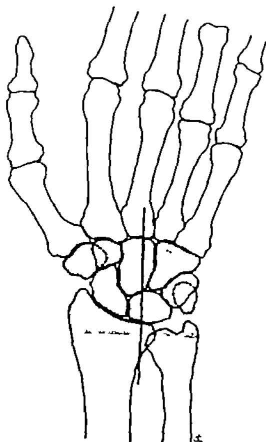


Fig. 621 —Line of incision for resection of carpus. Shaded area represents bone usually excised.

Technic.—A straight incision three inches in length is made over the dorsal surface of the wrist in line with the medial aspect of the shaft of the radius. Dissection is carried through the fascia and between the tendons of

the extensor indicis proprius and extensor pollicis longus tendons down to the radius, thence through the capsule of the wrist joint to the base of the third metacarpal bone The periosteum over the lower end of the radius and over the bases of the metacarpal bones is stripped away and the entire carpus excised The articular surfaces of the radius and ulna are removed down to normal appearing bone. Occasionally, excision of the proximal one half inch of the metacarpal bones may be necessary

After Treatment.—The wrist is immobilized in a cock up splint to maintain dorsiflexion or extension until the immediate postoperative reaction has subsided. Active exercise of the fingers is begun on the fourth or fifth postoperative day At the end of two weeks a cast is applied from the upper third of the arm to the heads of the metacarpal bones. After three months active exercises are instituted in the wrist the wrist being supported between exercise periods by a leather lacer brace reinforced with metal bars. The support may be discarded after the elapse of six months, provided function is adequate otherwise, a pliable wrist corset should be worn indefinitely The ultimate degree of function is seldom restored in less than one year

TREATMENT OF COMPLICATIONS

The number and severity of complications in tuberculosis of joints are in direct proportion to the duration of the tuberculous infection of the joint before treatment is instituted. If the primary focus is properly treated complications are much less likely to develop Despite efficient measures, however complications will arise during the course of the disease in a certain number of cases. Those which occasionally require surgery are abscess and paraplegia.

Tuberculous Abscess

In general, conservative or expectant treatment should have a thorough trial before operation is considered. Often the abscess will be encapsulated, and may or may not be walled off from the primary focus. Resolution may take place subsequently, with absorption of the abscess or the formation of a calcified mass. This is particularly true of abscesses associated with tuberculosis of the spine

A tuberculous abscess which increases in size if uncomplicated by a pyogenic infection, should be treated by aspiration followed by a compression bandage Incision should be avoided, if possible. If, after aspiration, the abscess continues to increase in size, causing pressure and consequent symptoms of interference with vital organs, such as paraplegia, dysphagia, dyspnea, or intractable pain, drainage may be employed As a rule, the contents of the abscess cavity are evacuated and an attempt is made to secure primary healing of the wound should healing take place the possibility of a secondary infection is avoided. The cavity however may refill, with the formation of a persistently draining sinus. If there is a complicating secondary infection, as evidenced by local and constitutional signs of an acute inflammatory process, drainage is instituted immediately as for any other pyogenic abscess.

Whether aspiration or drainage is employed, extreme caution should be exercised to protect the walls of the cavity from trauma Further the mass should be approached obliquely through healthy tissue by a scrupulously aseptic technic Even under the most favorable circumstances, a draining sinus may form particularly after repeated aspirations. In this event rigidly

aseptic treatment should be continued to prevent the development of a secondary pyogenic infection. If the abscess points in two localities, as frequently happens in psoas abscess, the most dependent portion should not be aspirated nor drained as healing is impaired by constant pressure on the tissues and sutures.

Abscesses may arise secondary to tuberculosis of any joint, but are most common in the hip and spine. The following discussion, therefore, will be limited to the surgical treatment of abscesses in these areas, although the principles described may be applied elsewhere.

TUBERCULOUS ABSCESSES OF THE HIP

In tuberculosis of the hip the roentgenogram frequently demonstrates wide distention of the capsule of the joint. If proper treatment is instituted, the lesion may remain intracapsular the capsule, however may rupture and the abscess may present subcutaneously in the adductor region the anterior surface of the thigh two or three inches below the anterior superior spine, laterally over the trochanter or in the gluteal region

Aspiration

For aspiration of a tuberculous cavity, a 15 gauge needle must be used in order that sufficient material may be withdrawn to make the procedure practicable large masses of inflammatory and necrotic tissue will block needles of smaller caliber After all tuberculous detritus is removed, a pressure bandage is applied. By this means, the walls may be compressed and fibrous tissue adhesions may form closing the cavity and preventing recurrence of the abscess. Rest in bed should be strictly enforced while conservative measures, especially heliotherapy are carried out.

Drainage

Surgical drainage of tuberculous abscesses of the hip is seldom if ever indicated unless an acute secondary pyogenic infection is present. Drainage is then employed as for any acute pyogenic process (p 201)

TUBERCULOUS ABSCESSES OF THE SPINE

Abscesses associated with tuberculosis of the spine may be palpable externally depending upon their size upon the vertebrae involved and the distribution of the adjacent fascial planes and musculature or they may present no outward manifestations until sufficiently large to cause pressure symptoms on various organs, as the pharynx or spinal cord

Tuberculous Abscess of the Lumbar Spine

When the lower dorsal or lumbar spine is involved in a tuberculous process, the abscess may appear as a lumbar or paravertebral mass. Usually however the tuberculous detritus gravitates along the course of the iliopsoas muscle forming an iliac abscess which presents just above Poupart s ligament or less commonly in Petit s triangle on the anterior surface or in the adductor region of the thigh or in the gluteal region Drainage is seldom required, since, as a rule, the process subsides under conservative measures.

If conservative treatment fails, the abscess generally ruptures spontaneously. Drainage may be necessary for relief of pressure symptoms or intractable pain or because of secondary pyogenic infection.

Drainage of a Paravertebral Abscess

A longitudinal incision three or four inches in length is made two to three inches lateral to the midline parallel to the spinous processes. The lumbodorsal fascia is divided in line with the incision and a hemostat passed

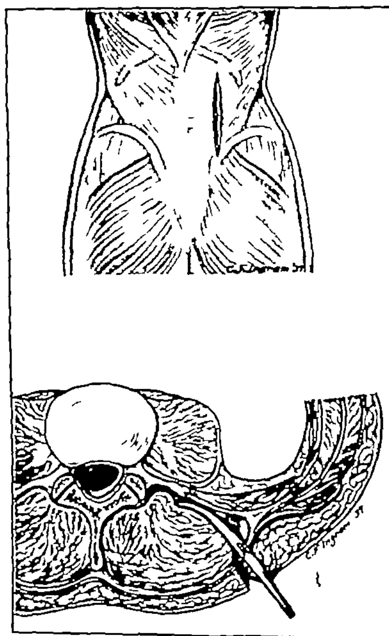


Fig. 622.—Drainage of paravertebral abscess.

bluntly around the lateral and anterior border of the erector spinae muscles to the transverse processes. Usually the abscess is encountered immediately if not the layer of the lumbodorsal fascia which separates the quadratus lumborum muscle from the erector spinae group is punctured and the hemostat forced along the anterior border of the transverse processes.

After Treatment.—A Penrose drain is inserted into the wound and maintained in situ by a nonabsorbable suture Conservative treatment, i e., the use of a Bradford frame and heliotherapy is carried out thereafter

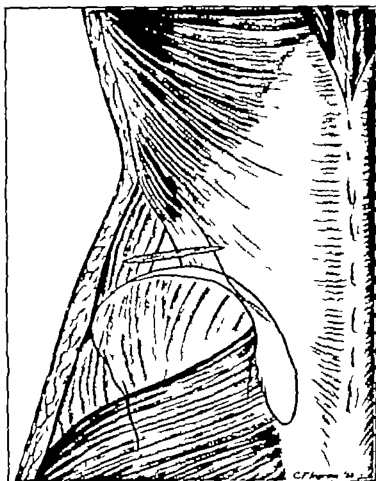


Fig. 423 —Drainage of pelvic abscess through Petit's triangle.

Drainage of a Psoas Abscess

Psoas abscesses are entirely extraperitoneal and follow the course of the iliopsoas muscle Drainage may be accomplished posteriorly through Petit's triangle, by a lateral incision along the crest of the ilium, or anteriorly under Poupart's ligament, depending upon the size of the abscess and the area in which it appears. Occasionally an abscess burrows beneath Poupart's ligament and presents subcutaneously in the upper third of the thigh, in the adductor region.

Drainage Through Petit's Triangle —The sides of this triangle are formed by the lateral margin of the latissimus dorsi muscle and the medial border of the obliquus externus abdominis muscle, and its base by the crest of the ilium The floor of the triangle is the obliquus internus abdominis muscle.

An incision three inches in length is made one inch above and parallel with the posterior crest of the ilium beginning lateral to the erector spinae group of muscles. After exposure of Petit's triangle, dissection is carried bluntly through the obliquus internus abdominis muscle directly into the abscess.

After Treatment.—After any incision for a psoas abscess, a rubber tube drain is inserted into the depths of the abscess and maintained *in situ* by stay sutures through the tube and edge of the incision. As flexion contractures of the hip usually accompany psoas abscess, a Buck's extension should be employed to correct the deformity and induce relaxation of the spastic muscles until the hip is fully extended.

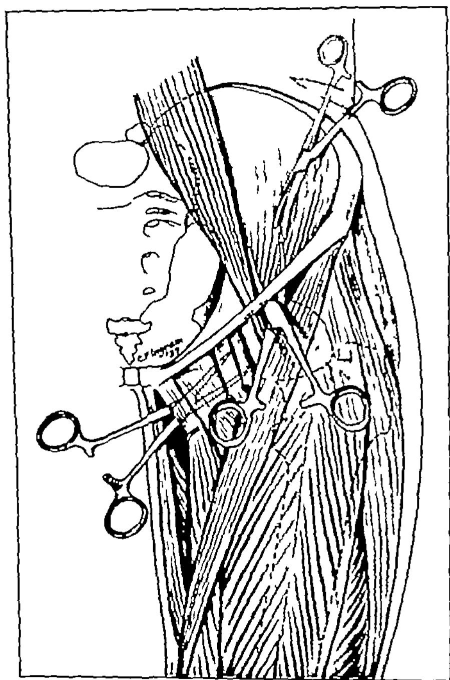


Fig. 424.—Drainage of psoas abscess. The hemostat in the adductor region is pointed toward the lower edge of the acetabulum; abscess is usually located nearer junction of head and neck. (Adapted from Freiberg, J. A., and Perlman, R.: J. Bone & Joint Surg. 18: 417, 1936.)

Drainage by the Lateral Incision.—A four inch incision is made along the middle third of the crest of the ilium, and the attachments of the internal and external obliquus abdominis muscles are freed. The abscess, which may then be distinctly palpated as a fluctuant extraperitoneal mass on the inner surface

of the wing of the ilium, is punctured with a hemostat. Care should be taken to avoid rupture of the peritoneum

Drainage by the Anterior Incision.—The skin is incised longitudinally on the anterior aspect of the thigh a distance of two to three inches, beginning at the anterior superior spine and continuing distally The sartorius muscle is identified and dissection carried deep to its inner border to the level of the anterior inferior spine. *The femoral nerve, which lies just medial to this area, should be protected.* A long hemostat is then inserted along the inner surface of the wing of the ilium under Poupart's ligament, puncturing the abscess. The blades are separated to widen the opening and permit complete evacuation.

Drainage by Ludloff Incision.—When a psoas abscess points subcutaneously in the upper third of the adductor region of the thigh drainage is accomplished by a Ludloff incision, as described on p 204.

Tuberculous Abscess of the Dorsal Spine

Abscesses of the dorsal spine, unless associated with paraplegia, rarely cause sufficient pressure symptoms to warrant evacuation. Generally the mass is well localized. If exceptionally large and associated with dyspnea of a spasmodic or asthmatic type, from pressure upon the respiratory tract or the recurrent laryngeal nerves, or both, drainage may be effected by costotransversectomy This procedure, originally performed by Heidenhain was described by Menard in 1894.

Technic.—(See p 929)

Tuberculous Abscess of the Cervical Spine

If the cervical spine is involved the abscess may present retropharyngeally in the posterior triangle of the neck or supraclavicular area, or the tuberculous detritus may gravitate downward under the prevertebral fascia to form a mediastinal abscess. Drainage of abscesses secondary to tuberculosis of the cervical spine is indicated in the presence of extreme dyspnea or dysphagia, or when rupture of a retropharyngeal abscess into the pharynx is imminent.

Drainage of a Retropharyngeal Abscess

Internal drainage of a retropharyngeal abscess, or incision through the posterior wall of the pharynx, is warranted only in dire emergency as indicated by extreme cyanosis and respiratory difficulty In this event, a tracheotomy set should be immediately available. The prognosis of this method is exceedingly grave, since pyogenic infection is inevitable. As a rule, retropharyngeal abscesses should be treated by external drainage.

Technic.—A three-inch incision is made along the posterior border of the sternomastoid muscle at the juncture of the middle and upper thirds. The superficial layer of cervical fascia is incised, the spinal accessory nerve which pierces the sternomastoid muscle and runs obliquely across the posterior triangle being protected from injury The sternomastoid muscle is retracted medially or incised transversely By blunt dissection, the levator scapulae and splenius muscles are defined and the abscess is palpated in front of the transverse processes and bodies of the vertebrae. The internal jugular vein is displaced forward as the finger palpates the abscess. The abscess wall is punctured and opened widely with the blades of a hemostat, and the contents

gently but thoroughly evacuated If the abscess is unusually large and symptoms are severe, the wound is allowed to remain open. A tracheotomy set should be available for use should the patient develop respiratory difficulty from edema of the larynx, or the abscess should accidentally rupture into the pharynx.

Kulowski mentions the following method of drainage An incision is made just anterior to the sternocleidomastoid muscle and blunt dissection is carried through the alar fascia between the cricoid and hyoid bones (neutral zone of Prentiss)

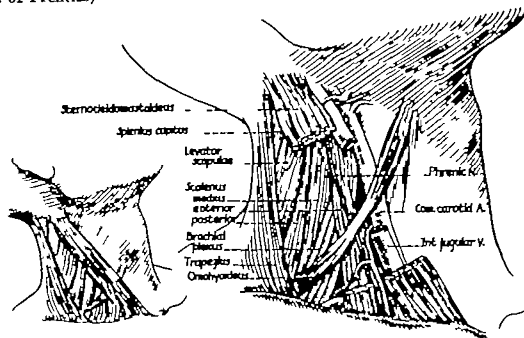


Fig. 625.—Drainage of tuberculous abscess of cervical spine.

Drainage of an Abscess of the Posterior Triangle of the Neck

The skin and superficial fascia are incised obliquely for two and one-half inches, following the posterior border of the sternocleidomastoid muscle The latter muscle is retracted medially the superficial nerves and external jugular vein being carefully avoided. The scaleni muscles should be identified without injury to the phrenic nerve The line of cleavage between the scalenus anticus and longus colli muscles is determined and divided by blunt dissection obliquely inward to the abscess beneath the prevertebral fascia. The cavity is evacuated and usually the wound is closed.

PARAPLEGIA

Paraplegia is most often associated with tuberculosis of the dorsal spine. The chief reasons for this are (1) tuberculous is more prevalent in the dorsal spine (2) the spinal cord terminates below the level of the first lumbar vertebra and (3) the spinal canal is smallest in this portion Seddon notes that the normal curve of the dorsal spine encourages a marked kyphos after destruction of the vertebrae and a squeezing of tuberculous products toward the cord. Further the anterior ligament in the dorsal region loosely confines the abscess, by contrast abscesses in the lumbar region can escape into the psoas muscle

The underlying pathologic process of paraplegia may be of several types (Seddon) In the paraplegia of early onset, a tuberculous abscess is the most

FIG. 626

SEDDON'S SUMMARY OF DIAGNOSIS, PREVENTION, AND TREATMENT OF PARAPLEGIA

	DIAGNOSIS	PREVENTION	TREATMENT
Type I			
ABSCESSES OF THE USUAL TYPE	No difficulty	Not always possible; hypertension of definite value	a. Primarily conservative b. Costo-transversectomy in any severe case likely to become Type II; continued activity of disease c. Incision of abscess in cervical cases, particularly if there is also marked pharyngeal obstruction
Type II			
ABSCESSES			
Posterior spinal disease	No difficulty	Not possible	Laminectomy
Spinal tumor syndrome	Accidental	Not possible	Laminectomy
MECHANICAL ACCIDENTS			
Pathological dislocation	Difficult	Hyperextension	Decompression
Compression by sequestrum or prolapsed disc	Difficult or impossible	Hyperextension	Decompression
Concertina collapse	Rapid onset typical x rays	Hyperextension	Decompression may be of value
THROMBOSIS	Rapid onset with only usual x ray findings	Not possible	Useless
Type III			
Reactivation of tuberculous focus inside spinal canal	No difficulty	Efficient treatment of tuberculous spine at every stage	Conservative in severe cases, anterolateral decompression and removal of tuberculous material

Composite of Tables from Brit. J Surg. 22: 769 1934 1935 and Proc. Roy Soc. Med. 39: 723 1946.

FIG 627

SEDDON'S SUMMARY OF PROGNOSIS

VERY FAVORABLE	UNFAVORABLE	HOPELESS
Paraplegia in extension (incomplete cord lesion)	Sphincter involvement	Paraplegia in flexion (complete cord lesion)
Voluntary control never lost		Flaccid paralysis (except in cauda equina and brachial lesions)
Voluntary control absent for not longer than six months	Pregnancy	Loss of voluntary control longer time than six months
Absence of sensory loss		Loss of vibration sense
Absence of sphincter involvement		Old age

From Brit. J Surg. 22: 769 1934 1935.

common offender mechanical accidents from interruption of the continuity also contribute to the etiology though less commonly Intrinsic cord lesions without compression may rarely be the responsible factor This pathologic state is not too well understood but may be due to edema from vascular stasis or local toxicity Changes in the cord ordinarily are the result of pressure from abscesses or mechanical accidents. Thrombosis of the vessels to the cord is another lesion that must be considered

Seddon subscribes to Butler's postulates that paraplegia of late onset is ordinarily due to exacerbation of a tuberculous mass inside of the spinal canal.

He admits the existence of pachymeningitis in some cases of paraplegia but denies that a causal relation to paraplegia has been established

Butler and Seddon have suggested the following clinical classification of these cases.

Paraplegia of Early Onset

Type 1.—Paraplegia with early active tuberculosis, arising persisting and recovering in direct relationship to the activity of the disease. The paralysis usually appears within the first two years and develops rapidly through the following stages muscle weakness, spasticity, and incoordination, progressing to paraplegia in extension and later into paraplegia in flexion In paraplegia in extension the cord is not completely involved certain nerve tracts continuing to function whereas in paraplegia in flexion the whole thickness of the cord is affected. In the most severe forms, all spasticity disappears and the paralysis becomes flaccid, in these, the outlook is grave

Paraplegia induced by compression of the cord by an abscess is usually treated conservatively with rest in bed and extension If no response is observed within a reasonable period of time after loss of voluntary control Butler and Seddon advise surgery in the presence of an abscess of the dorsal spine a costotransversectomy is performed, whereas an abscess in the cervical spine is incised and drained If the disease is in the neural arch, compressing the cord from behind laminectomy is performed.

In a recent communication (1948) Seddon states We now decompress the cord as soon as voluntary power has been lost or spasm of the lower limbs is so severe as to make nursing difficult and interfere with proper immobilization of the spine We take the risk of doing a few unnecessary operations, some of the patients might get better if left alone On the other hand I think more is gained by cutting short the duration of the paraplegia, so enabling one to concentrate on the treatment of the bony lesion itself. Furthermore, if a costotransversectomy has been done early and recovery from the paraplegia does not follow within, say six weeks the chances are that the paraplegia is due to a mechanical accident, the presence of the abscess being purely coincidental By doing costo-transversectomy earlier one still has time in hand for a second more radical operation should the costotransversectomy fail to give relief."

Type 2—Paraplegia which appears with early active tuberculosis but persists permanently even though the disease becomes quiescent. In its early stage, this type is usually indistinguishable from Type 1 The paralysis soon becomes complete occasionally first showing some degree of recovery In the majority of cases, the permanence is the result of inadequate treatment in the early stages, though it may be unavoidable because of a sudden mechanical or vascular disaster There are three clinicopathologic types

1. Paraplegia of sudden onset rapidly becoming complete This may follow collapse of a single vertebral body ("concertina collapse) as revealed by the roentgenogram, or it may be from an acute thrombosis of the spinal cord in the latter event the roentgenogram will show only the usual changes, and operative treatment is of no avail. In the former decompression may be of value

2. Spinal tumor syndrome resembling that of an intraspinal tumor This type is rare, beginning under the posterior ligament and is the only form of Pott s paraplegia wherein neurologic signs precede the roentgenographic appearance of tuberculous changes. Laminectomy is, of course the only immediate means of confirming the diagnosis and is the proper treatment.

3 Paraplegia which is identical in onset to Type 1, but persists in severe form for many months. The persistent paralysis may be attributed to either of the following

a Pathologic dislocation incident to destruction of the posterior vertebral arch, with resulting dislocation and cord compression The treatment of this condition is laminectomy and fusion

b Compression by sequestra or a prolapsed disc being forced back into the spinal canal by the collapse of the vertebral bodies. The diagnosis of the pathologic lesions listed in *a* and *b* is difficult or impossible Decompression of the cord is essential.

c. Continued activity of the disease. The signs of continued activity are irregular fever wasting progression as evidenced by the roentgenogram, and enlargement of the cold abscess occasionally also, new foci may develop in the spine itself or elsewhere in the body In these cases, costotransversectomy may be indicated.

Paraplegia of Late Onset

Type 3—Paraplegia of late onset, appearing even many years after the disease has become quiescent and without evidence of reactivation, is usually incomplete. With the passage of time this type follows one of two courses (1) Recovery takes place under the usual conservative treatment (2) no recovery takes place under any treatment.

Unless operation is indicated the treatment consists of prolonged bed rest. Hyperextension is of no value. Laminectomy is beneficial if it appears from the roentgenogram that the cord is stretched over the bony ridge and removal of the bony ridge seems advisable. *If a fresh abscess is in evidence a costotransversectomy* should be performed.

Girdlestone takes a somewhat similar view in regard to the treatment of Pott s paraplegia It is his opinion that many patients have needlessly been allowed to become permanently paralyzed as a result of conservative treatment, whereas they would have recovered had either costotransversectomy or laminectomy and fusion been employed early Partial motor paralysis without sensory loss or sphincter derangement is favorable and can, he feels, be watched for one or two months under conservative treatment. In the presence of roentgenographic evidence of compression however, the period of watching should be brief If the paralysis is gradually increasing, he feels that to allow compression of the cord to continue is inexcusable, and advises decompression even during the active stages of the tuberculous process. The longer the paraplegia persists, the less the likelihood of recovery from either conservative or operative treatment. Following total motor paralysis of more than six months duration, the prospect of complete recovery is slight. On the whole, he believes it is better to operate early upon a small number of patients who would recover without operation than to risk irreparable damage to the cord through delay

In general, Girdlestone s indications for operation are

A. Neurologic A paraplegia

a Arising in the course of efficient treatment

b Progressing or showing no improvement with adequate treatment

c Already advanced

B Roentgenographic A paraplegia associated with roentgenographic evidence or suggestive evidence of compression by

a Tense paravertebral abscess

b Bony angle, ridge, sequestrum or disease of the posterior vertebral elements. If the disease is in the posterior portion of the vertebra the roentgenogram is sometimes negative and the diagnosis may be suggested by more severe involvement of the sensory tracts than of the motor tracts of the cord

C Neglected complete paraplegia of many months' duration He believes that these patients should be given a chance of recovery, regardless of how slight, by laminectomy and uninterrupted immobilization

According to the general opinion however, conservative treatment should be well tried before surgery is considered Hyperextension on a Bradford or Rogers frame, or immobilization in a hyperextension cast will bring about recovery in the majority of cases, particularly if the paralysis is still in the spastic state. After the muscles have become flaccid, recovery is extremely doubtful following either conservative or radical measures. In every case, fusion of the spine should be carried out after the paralysis has disappeared

Surgical procedures for Pott's paraplegia consist of (1) costotransversectomy (2) laminectomy, and (3) laminectomy and fusion of the spine.

Costotransversectomy

Girdlestone has performed costotransversectomy alone or in conjunction with laminectomy, in an ultimate effort to relieve spinal cord compression in paraplegia. Mercer gives the following advantages of costotransversectomy 'It attacks the main cause of the paraplegia, the abscess cavity, and by emptying the abscess reduces the pressure on the cord and the toxicity of the focus. Drainage of the material after costotransversectomy is away from the cord—not around it as after laminectomy The operation does not weaken the bony spine The technic is not difficult, nor is there any great operative risk.' Steindler observed that, of twenty three patients with posterior mediastinal abscesses, paraplegia from extension of the abscess was present in fourteen. He concluded that evacuation of the abscess by costotransversectomy is a thoroughly rational procedure and a rapid recovery is likely

Technic.—A midline incision is made over three spinous processes on the side of the larger abscess shadow The periosteum and soft tissues are reflected laterally from the spinous processes and laminae, and the middle transverse process is fully exposed and resected at its base. The periosteum is reflected from the contiguous rib and the latter is removed two inches from the tip of the transverse process. The end of the rib is beveled smoothly, with care to avoid puncture of the pleura. The abscess cavity is opened by blunt dissection close to the vertebral body The opening should be sufficiently wide to permit thorough exploration of the cavity and removal of all debris. If resection of more than one rib is necessary the initial incision is enlarged accordingly the ribs having been resected, the intervening neurovascular bundle is doubly ligated and divided.

In some cases, the wound may be closed after thorough evacuation of the cavity Ordinarily however a petrolatum gauze wick is inserted and left in situ for forty-eight hours to prevent secondary pressure. If a sinus forms, it must be protected against secondary infection by meticulous asepsis.

Technic (Kocher).—The incision begins over the most prominent spinous process and extends laterally along the course of the rib to be resected. The

latissimus dorsi and muscles of the spine are divided in the line of incision, exposing the transverse process and rib The subsequent procedure is identical to that described above.

Kocher states that division of the spinal muscles has no adverse effect upon the result.

Technic (Bickham).—A four inch vertebral incision is made one-half inch from the midline, the center of the incision being over the affected vertebra. A second incision parallel with the course of the rib to be resected is carried from the center of the first incision downward and laterally The technic thereafter is similar to that described above.

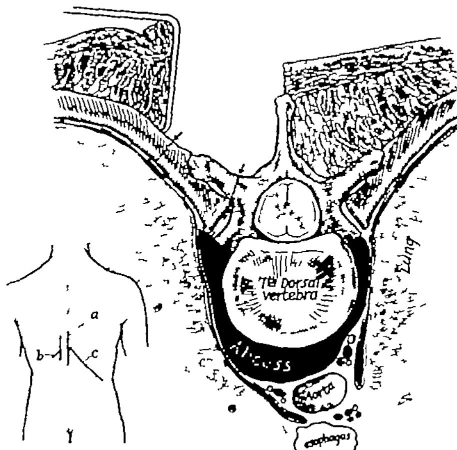


Fig. 628.—Costotransversectomy for drainage of tuberculous abscess of dorsal spine. a, Midline incision. b, Bickham incision. c, Kocher incision.

Laminectomy

Prior to operation a thorough neurologic examination should be made to determine the exact sensory level and the level of the physiologic block these may be higher or lower than the affected area of the spine. The laminectomy should be performed at the level of the sensory change for usually the sensory level the intraspinal pathologic process, and the apex of the kyphos correspond.

Technic.—The technic of laminectomy for paraplegia associated with tuberculosis is similar to that for fractures of the spine with paraplegia (p 452) with the following exceptions Because of the fusion which has been or is to be performed, the laminectomy should be longer and narrower All tuberculous detritus is removed and any constricting bands are resected. The dura is never opened.

Laminectomy and Fusion of the Spine

Many authors criticize complete laminectomy on the basis that the spine is thereby structurally weakened. This disadvantage may be overcome by fusion (Girdlestone) or by a hemilaminectomy (Albee). In the latter, the articular facets and laminae on one side are preserved, and further support may be added if necessary, by the insertion of a curved bone graft into the split spinous processes.

Technic (Girdlestone).—An incision is made in the midline over the spinous processes of the three vertebrae from which the laminae are to be removed as well as over the two above and two below. With a motor saw or osteotome, two osseus flaps with periosteum intact are turned down from each side of the spinous processes of the two proximal and two distal vertebrae. The bases of the flaps are separated from the laminae with an osteotome and retracted laterally. The laminae of the middle three vertebrae are fully exposed and removed with rongeurs. All tuberculous detritus is evacuated. Two bone grafts, each approximately three-eighths inch wide, are removed from the tibia and inserted into the prepared beds, their smooth outer surfaces being turned toward the dura. The lateral osteoperiosteal flaps are then sutured over the two grafts and the wound is closed. If only a moderate kyphosis is present, the spinous processes and laminae of the distal and proximal vertebrae support the graft, preventing its pressure upon the cord. If kyphosis is extreme, curved or flexible grafts (p. 130) may be utilized.

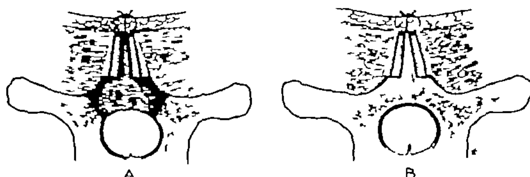


Fig. 621.—Laminectomy and fusion of the spine. B, Grafts supported by laminae of vertebrae distal and proximal to laminectomy, thereby, A, preventing contact between grafts and spinal cord. (Redrawn from Girdlestone, G. R.: Brit. J. Surg. 19: 71, 1931.)

After Treatment.—The patient is kept on a Bradford frame for two weeks. The stitches are then removed and a cast is applied from above the nipple line to the knees on both sides. After eight weeks, the cast is discarded and the Bradford frame is resumed until all symptoms of paraplegia have disappeared. The patient may then be allowed up, although the spine should be supported for at least one year by a long Taylor spine brace.

Technic (Albee).—Through a curved longitudinal incision, the spinous processes of six vertebrae are exposed and the periosteum and soft tissues are reflected laterally from the spinous processes and laminae of one side. The laminae on this side are resected bringing the dura into view. The spinous processes are split with an osteotome, one half being reflected to the side opposite the laminectomy. A cortical graft of proper length is taken from the tibia (p. 127) and inserted into the prepared bed.

After Treatment.—See above.

AMPUTATION

Amputation is indicated in tuberculosis of joints when the disease process is so extensive that a permanent cure appears impossible. In adults, if the lesion involves several tarsal bones, the ankle or knee, and is complicated by secondary infection as evidenced by numerous draining sinuses, an artificial limb is preferable to a long convalescence with the probability that the infection may continue despite every conservative or radical treatment. This is particularly true if the patient is an elderly individual, or one whose finances will not permit prolonged periods of hospitalization. The operation should be carried out well proximal to the affected joint.

Mitchell in an excellent study of tuberculosis of the ankle and tarsus, points out that the disease is much more prone to assume a malignant character in adults than in children especially in elderly individuals. He advises upper tibial amputation without delay for patients over forty five years of age, and considers amputation for those from thirty five to forty five if in poor condition. He also recommends that patients from seventeen to thirty five years of age be treated conservatively for six months if definite evidence of healing is observed at the end of that time, conservative measures should be continued. If at any time progress is arrested for longer than three months, however amputation should be immediately performed.

Extensive amyloid disease adds to the necessity for amputation. Further the appearance of a pulmonary infection following the development of an osseous lesion is not uncommon for this reason these patients should have repeated roentgenographic examinations of the chest during the period of conservative treatment.

ARTHRODESIS

All operations for fusion of tuberculous joints will be described in the following chapter

References

Albee, Fred H. Orthopedic and Reconstruction Surgery Philadelphia, 1919 W B Saunders Co., p 860.

Albee Fred H., Powers, Earl J., and McDowell, Harold C. Surgery of the Spinal Column, Philadelphia, 1945, F A. Davis Co.

Bickham, W S.: Operative Surgery Philadelphia, 1924, W B Saunders Co., Vol. II, p 829

Burghard F F: A System of Operative Surgery, London, 1914 Henry Frowde, Vol. II, p 46.

Butler H. Weeden Paraplegia in Pott s Disease, With Special Reference to the Pathology and Etiology Brit. J Surg 22 738, 1934-35.

Campbell, Willis C., and Smith, Hugh: Injuries and Surgical Diseases of Joints. Dean Lewis Practice of Surgery Hagerstown, 1940 Vol. II Chap. V W F Prior Co., Inc.

Davidson, A. J., and Horwitz, M. T: Resection of the Elbow Joint, Surgery 3 226, 1938.

Deery E. M: Laminectomy for Pott s Paraplegia, Ann. Surg 124 201, 1946.

Erlacher Philipp J: The Radical Operative Treatment of Bone and Joint Tuberculosis, J Bone & Joint Surg 17: 536, 1935.

Fraser John: Tuberculosis of the Bones and Joints in Children, New York, 1914, The Macmillan Co.

Gaenslen, F J Split Heel Approach in Ostomyelitis of Os Calcis, J Bone & Joint Surg 13: 759 1931.

Geist, Emil S. Anterior Tarsectomy (Ollier) in Tuberculosis of the Anterior Tarsus, J Bone & Joint Surg 8 410 1926.

Ghormley Ralph K., and Brav Ernest A.: Resected Knee Joints, Arch. Surg 26 465, 1933.

Girdlestone, G R.: Tuberculosis of Bone and Joint, London 1940 Oxford University Press.

Kite, J H. Tuberculosis of the Spine With Paraplegia, South. M. J 29 883, 1936.

Kocher T: Textbook of Operative Surgery London, 1911 A. and C. Black, Ltd., p. 491

Lucarelli, G : Tibio-Astragaloid Tuberculosis and Tuberculosis of the Tarsus, Internat. Abst. Surg 59 542, 1934. (Abstracted from Clin. chir 10: 453 1934.)
Mercer Walter: Orthopaedic Surgery ed. 3, New York, 1943, Longmans, Green & Co.
Miltner, Leo J., and Fang, H. C.: Prognosis and Treatment of Tuberculosis of the Bones of the Foot, J Bone & Joint Surg 18 287 1936.
Miltner Leo J., and Wan, F E Giant-Cell Tumor of the Os Calcis, J Bone & Joint Surg 14 406, 1932.
Mitchell W R D End Results and Treatment of Tuberculous Disease of Ankle and Tarsus, Brit. J Surg 28 71, 1940
Murphy, J K. The Radical Treatment of Tuberculous Disease of the Tarsus and Ankle-Joint, Brit. M. J 2 1145, 1910.
Pouzet, F: End Results of Resection of the Calcaneus for Tuberculosis, Internat. Abst. Surg. 52 550 1931 (Abstracted from Rev d'orthop 37 627, 1930)
— Tuberculosis of the Calcaneum in Children Internat. Abst. Surg 52: 56 1931. (Abstracted from Rev d'orthop 17 301 1930.)
Seddon, H. J: Pott s Paraplegia Prognosis and Treatment, Brit. J Surg 22 769, 1934-35.
Seddon, H. J., and Alexander G L. Discussion on Spinal Caries With Paraplegia, Proc. Roy Soc. Med. 39 723, 1946
Shands Alfred Rives, Jr., and Raney Richard Beverly: Handbook of Orthopaedic Surgery, ed. 2, St. Louis, 1940 The C. V Mosby Co.
Steindler Arthur: Posterior Mediastinal Abscess in Tuberculosis of the Dorsal Spine, Thirty Third Report of Progress in Orthop Surg., p. 2 (Abstracted from Illinois M. J 50 201 1926.)
— A Textbook of Operative Orthopedics, New York, 1925, D Appleton & Co.
— Diseases and Deformities of the Spine and Thorax, St. Louis, 1929 C. V Mosby Co.
—: On Paraplegia in Pott s Disease, Journal Lancet 54 281 1934
Tubby A. H.: Deformities Including Diseases of the Bones and Joints, London, 1912, Macmillan & Co., Ltd.
Willis, T A.: Pott's Abscess, Surg Gynec. Obst. 43 285 1926.

CHAPTER XV

ARTHRODESIS

Arthrodesis is an operation designed to induce bony ankylosis of a joint in which motion may be undesirable The abnormalities which necessitate arthrodesis are (1) tuberculosis of the joint (2) anatomic incongruity of the articular surfaces following (a) trauma, including fractures, or (b) osteoarthritis or destructive processes, in either of which the disease has entirely subsided, leaving the joint with impaired motion pain, and disability and (3) gross instability or loose, flail joints, usually the result of (a) anterior poliomyelitis or (b) trophic affections of joints, as Charcot's joints.

The operations for fusion of joints for incongruous articular surfaces from trauma or instability differ somewhat from those employed for tuberculous lesions. In the former, the joint may be entered with impunity, and the articular cartilages excised down to healthy cancellous bone approximation may then be effected with every prospect of osseous union and without the risk of instigating a more serious process. Further union takes place in a much shorter period of time since in the majority of cases, the structure of the bone and surrounding soft parts is not altered by an active infection. In tuberculous lesions there is danger of relighting an infection.

The majority of operations for inducing ankylosis will be described as for the treatment of tuberculosis. Fusion operations which are more suitable for nontuberculous joints will be described in a separate section (p 994)

ARTHRODESIS OF TUBERCULOUS JOINTS

In tuberculous joints arthrodesis is carried out to immobilize the affected joint and thus enforce rest until nature obliterates the pathologic process. Conservative orthopedic measures have a similar purpose, although clinical experience has proved that the arrest of the process is more complete and lasting by osseous ankylosis, and fusion permits a better fixation than can possibly be maintained by apparatus. For successful results, however, measures which tend to improve the condition and natural resistance of the patient, must be constantly and rigidly enforced in both adults and children fusion is only a valuable adjunct and, alone, is not to be regarded as curative. Who knows what the antibiotics or drugs of the future may accomplish?

The operative technic for fusion may be (1) intra-articular (2) intra and extra-articular or (3) extra articular

Intra-Articular Arthrodesis

By this method the articular surfaces are denuded to permit the approximation of cancellous bone No attempt is made to excise all diseased tissue since this is impossible An intra-articular procedure affords a better correction of deformity if present On the other hand, the resistance of the osseous tuberculous tissue is poor and union is slow and uncertain, further activation of a virulent process is more likely In children, the preponderance of cartilage adds to the difficulty of obtaining fusion by intra-articular operations. Because of these disadvantages, the intra-articular technic is supplemented when feasible by extra articular arthrodesis.

Intra-Articular and Extra Articular Arthrodesis

A combination of intra-articular and extra articular procedures is more commonly employed in both tuberculous and nontuberculous joints. In tuberculous lesions, the capsule and synovium are incised to permit the insertion of autogenous osseous grafts across the joint. The articular surfaces are denuded as little as possible. By this technic, osseous fusion is induced largely outside the articulation though within the capsule

Extra-Articular Arthrodesis

The purpose of extra-articular fusion is the induction of union entirely outside the capsule of the joint, between osseous surfaces of normal bone In all tuberculous joints, extra-articular arthrodesis is the procedure of choice when practicable The likelihood of fusion varies, however, with the anatomy of the joint. Arthrodesis of the spine is most successful, being confined to normal bone unless the disease has extended to the laminae and spinous processes.

Many of the extra-articular technics primarily devised for tuberculous joints may be combined advantageously with intra-articular technics for fusion of nontuberculous joints.

Indications and Contraindications for Arthrodesis

The indications for fusion of the joints differ to some extent according to the age of the patient, the location and the evolutionary stage of the pathologic process. In practically all patients above the age of 8 years, ankylosis by osseous fusion is preferable when no complications are present. This age is not arbitrary but may vary from 6 to 10 years, depending upon the development of the skeletal structures. Osseous ankylosis is more certain in adults than in children, since cancellous bone is near the articular surface, thus facilitating union. In children between the ages of 3 and 5 years, when the incidence of tuberculosis of the joints is highest, the abundance of cartilage within the joint surfaces makes osseous ankylosis difficult this has been proved by attempts to fuse paralytic joints. Further if the epiphyseal plates are violated, material shortening and deformity will result. It has been demonstrated by McKeever however and confirmed in this clinic, that intra articular arthrodesis of the knee may be safely and easily performed even in young children, with less residual shortening and with a lower incidence of complications than following conservative treatment for a period of years. Kite is of the opinion that the spine may be safely fused in young children and deplores the continued conservative treatment as practiced by many orthopedic surgeons.

Fusion may be more readily obtained if the operation is performed in the early stage of the disease, before extensive destructive changes have taken place in the bone or after the lesion has apparently become quiescent and the density of the osseous structures approaches normal. An actively destructive process, with acute symptoms, endangers the possibility of bony union in addition there is more risk of increasing the intensity of the tuberculous process and inducing secondary infection. Hence, operation at this stage should be undertaken only after serious deliberation. Even in the presence of abscesses, draining sinuses, and secondary infection, some authorities advocate arthrodesis of tuberculous joints In such practices we do not concur as there is a probability of exacerbation of both pyogenic and tuberculous infections, persistent draining sinuses and even metastasis to a vital organ with a consequent fatal termination.

Treatment of Deformities Associated With Tuberculosis of a Joint

Deformities should be corrected, *so far as possible before arthrodesis* is attempted. Brisement forcé, especially of the hip or knee is definitely contraindicated in the treatment of a tuberculous joint as metastasis, particularly tuberculous meningitis, may follow. When organic changes are present to such a degree that correction cannot be accomplished by conservative means (Chap. II) surgical correction may be effected at the time of fusion. The procedures should be entirely extra-articular when possible, consisting of severance of all contracted soft structures and osteotomy.

ANKLE

Posterior Arthrodesis

A posterior arthrodesis of the ankle has several advantages over the anterior method, subsequently described. First, should equinus deformity be present, correction may be easily accomplished through the posterior

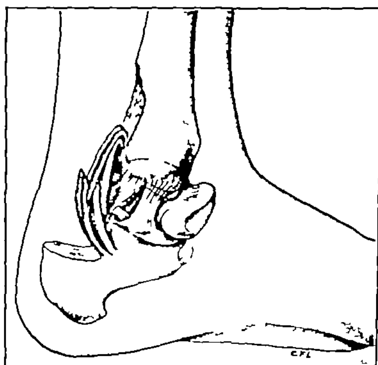


Fig. 439.—Posterior extra-articular arthrodesis of ankle.

incision by lengthening of the tendo achillis. Further the subastragalar joint, being intimately connected with the ankle joint may be involved in the tuberculous process. By the posterior technic, ankylosis may be induced in the subastragalar articulation as well as in the ankle. As the operative trauma to the bone and soft tissues is nominal and well beneath the surface, the reaction is much less severe than that incident upon the anterior approach. The procedure may be entirely extra-articular. A sufficient degree of compensating motion is secured in the midtarsal joints to obviate the disadvantage of fusion of the subastragalar joint.

Technic (Campbell).—An incision three inches in length is made over the posterior aspect of the ankle joint, medial to and parallel with the tendo achillis, and is carried down between this structure and the posterior capsule.

The flexor hallucis longus tendon is retracted medially. The posterior capsule is not incised. By means of an osteotome large flaps of bone are turned downward from the posterior aspect of the tibia and upward from the superior surface of the os calcis, overlapping at the level of the ankle joint and thus providing a massive extra-articular bony bridge across the joint.

After Treatment.—The ankle is immobilized in a plaster cast which extends from the toes to well above the knee, the foot being held at a right angle. To allow for swelling a window is cut in the cast over the dorsum of the foot, then replaced and held loosely with bandages. After four weeks another snugly fitting boot cast is applied, or if the postoperative reaction has been mild, a walking cast will suffice. Weight bearing is cautiously resumed; full weight bearing is usually delayed for eight to twelve weeks after operation. The cast is removed at the end of three months, a leather corset brace with steel reinforcement is applied, and a shoe is fitted over the brace. This apparatus is worn for a period of three to six months, depending upon the local reaction. Solid union usually is demonstrated at the end of three months, and in some cases earlier.

The end results of this operation are excellent. The patient generally acquires an almost normal gait, although walking on irregular surfaces may be difficult; this disability is slight when compared to the patient's former status. We have also employed the technic for fusion of incongruous joints, with similar success. (See section on Arthrodesis of Nontuberculous Joints.)

KNEE

Tuberculosis of the knee joint is best treated by arthrodesis during the early stage of the disease, before deformity occurs. In untreated cases, deformity is often severe after the disease process has subsided, the extremity being fixed in flexion, abduction and external rotation with partial or complete subluxation of the tibia on the femur. If the deformity is mild at operation sufficient bone may be removed from the condyles of the tibia and femur to permit approximation of the osseous surfaces with the knee in the most serviceable position. Conservative or operative treatment must be employed prior to fusion if deformity is pronounced. Flexion of the knee may be corrected by special apparatus (p. 37) or these measures may supplement operative procedures such as posterior capsulotomy (p. 1020) or osteotomy (p. 1033). Forcible correction should not be attempted. When the maximum degree of correction is obtained, which usually requires from two to four weeks, an intra-articular arthrodesis and further correction of the deformity may be carried out.

Intra-Articular Arthrodesis of the Knee

To avoid repetition the following technic will be referred to in subsequent discussions of fusion operations as routine intra-articular fusion of the knee. The essential principles of the procedure are employed in many operations which include the use of bone grafts, nails and pegs, and exogenous materials.

Technic.—The joint may be approached through a U shaped incision or an anteromedial incision. The latter is more suitable if exposure above and below the articular surface is required.

The U incision begins at the level of the femoral condyle and curves downward and across the knee below the patella, thence upward to the oppo

site condyle The patellar tendon is incised and a flap consisting of patellar tendon, patella, quadriceps tendon and a large portion of the terior capsule is turned upward When the interior of the joint is reached, cruciate ligaments are severed to permit free access to the articulation. If synovium is involved by the disease process, anterior synovectomy is carried as completely as practicable. If there are bony cavitations these are thorou curetted. No effort is made, however, to eradicate all the diseased tissue.

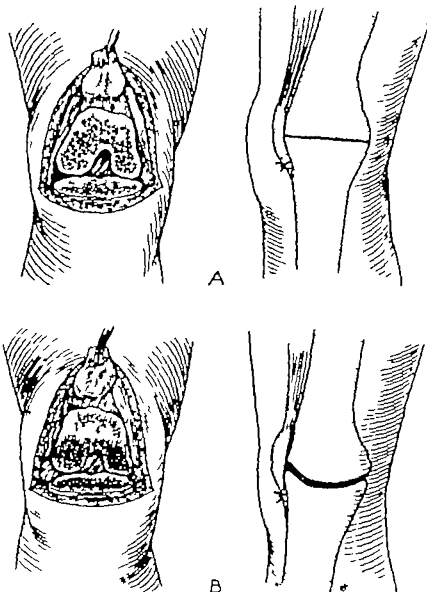


Fig. 631 —Intra-articular arthrodesis of knee. *A*, Excision of bone, forming two flat surfa *B* Excision of bone to conform to normal articular surfaces.

Following the normal contour of the joint surfaces, the encrusting cartil together with a thin layer of superficial bone from the tibia and femur is cised with a hand saw or the ends of the bones may be excised transvers to form two flat surfaces Resection should be limited to the minimum quirement for satisfactory apposition of cancellous bone. Removal of pathologic bone is unnecessary and in children is inadvisable as wide res tion destroys the epiphyses. If the knee is in valgus, a commensurately lar portion of bone must be removed from the internal condyles of the ti

and femur, and only a small amount from the external condyles. If there is a flexion contracture, sufficient bone is removed to correct the deformity. After completion of this step in the procedure, the osseous surfaces should be exactly approximated with the knee in the most serviceable position. In children, the knee usually is placed in extension since flexion deformity tends to recur as growth ensues, further extension causes less abnormal stress upon the upper tibial epiphysis. In adults 160 degrees is the most serviceable position for walking or sitting. Should this position not be possible because of extensive destruction, the knee is placed in extension in order to secure the maximum approximation. The posterior surface of the patella and the corresponding portions of the femur and tibia are then denuded and approximated, or in the presence of excessive destruction the entire patella is excised.

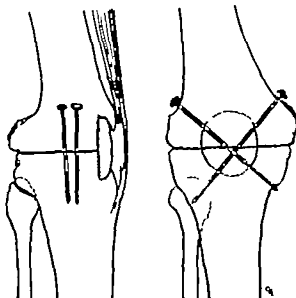


Fig. 632.—Usual technic of fusion, Knowles' pins being utilized for internal fixation.

Regardless of the technic of fusion employed, we believe that the use of transfixion nails, as described below in the Henderson operation, or Knowles pins is advantageous. After trying all methods in an effort to maintain contact of the osseous surfaces, we are convinced that fusion takes place in a much shorter time when some form of internal fixation is utilized.

After Treatment.—The extremity is placed in a plaster cast from the toes to above the crest of the ilium and a generous window is cut out over the knee. After all swelling has subsided, which usually requires three or four weeks, another closely fitting cast is applied. If, at the end of twelve weeks, fusion has progressed sufficiently the limb is encased in a leather corset which is attached to a Thomas caliper knee brace. The corset is made to fit snugly and accurately by being molded upon a plaster model of the leg. This apparatus is suitable for use both day and night until fusion is solid and should be worn for approximately six months, or until the roentgenogram demonstrates complete osseous union. Following arthrodesis of the knee children in some instances, should continue the use of a long leg brace without a knee joint until the age of fourteen. In the event of a fall, this serves to prevent a supracondylar fracture of the femur or a traumatic separation of the distal femoral epiphysis.

Key has augmented the routine intra articular procedure by inserting a stainless steel pin (3/16 inch for adults and 5/32 inch for children) through the lower third of the femur well above the field of operation, and another through the tibia below the condyles. The pins are placed parallel to each other and at the proper distance apart to be fitted into an extended turn buckle. Following application of a cast from the groin to the toes, a circular section is removed at the knee and the turnbuckles are tightened to maintain firm contact of the ends of the bones. The tightening is repeated as often as necessary the degree of pressure being determined by the bend of the pins. After eight weeks, if union is solid, the pins are removed and a snugly fitting cast is applied, this is worn for eight additional weeks before weight-bearing is allowed

Excessive pressure from poor adjustment of the turnbuckles will lead to atrophy and necrosis of the approximated surfaces and thus interfere with osteogenesis. Contact of the osseous surfaces with complete fixation but without undue pressure is, however, essential to rapid osseous fusion.

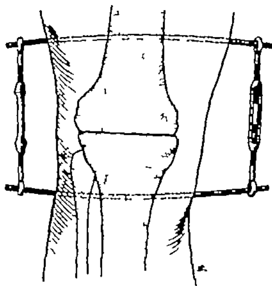


Fig 631.—Maintenance of apposition of raw surfaces of tibia and femur by pins and turnbuckles (Key)

Arthrodesis of the Knee With Patellar Graft

Hibbs devised an operation for flail knees in which the patella was used to induce fusion. Later he applied the technic in the treatment of tuberculosis of the knee The patella acts as a graft to unite the femur and tibia anteriorly and in this position forms a bony bridge between the tibia and femur If only the anterior portion of the condyles of the femur and tibia is removed the surgical reaction is less severe further the healing process is hastened and the danger of secondary infection or of relighting a quiescent process is materially diminished. In children, although the epiphyses are not disturbed at operation, there may be some deformity as growth progresses.

Galloway Henderson, and Albee subsequently modified Hibbs operation, completely resecting the articular surfaces and employing a slightly different technic in other respects. In the opinion of some surgeons, removal of all pathologic bone in adults is a decided advantage. The majority of surgeons do not attempt such a wide resection, but remove only enough of the surface and underlying bone to allow satisfactory apposition of cancellous tissue.

In the Hibbs and Galloway procedures, the patella is left attached to the quadriceps tendon, that the blood supply may be preserved. Unless the joint surfaces are amply resected, however, or if the knee is to be fused in 160 degrees' flexion there may be difficulty in inserting and maintaining the patella across the joint without detaching the tendon. Utilization of the patella as a free graft is not a serious disadvantage in that the graft is rapidly revascularized as a rule, if morticed into the cancellous bone flaps or grooves on the femur and tibia.

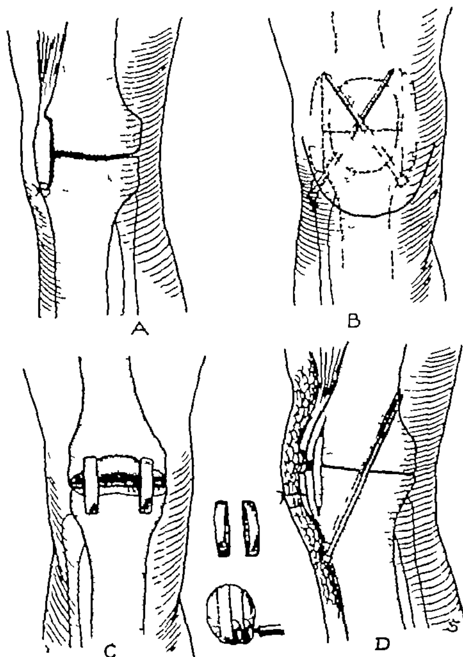


Fig. 634.—Arthrodesis of knee with patellar graft. *A* Hibbs technic. *B*, Galloway technic with Knowles' pins. *C* Albee technic. *D* Henderson technic with Knowles' pins.

Technic (Hibbs).—Through a U shaped incision the insertion of the patellar tendon is severed close to the tibial tubercle, and the patella and patellar tendon are turned upward. The patella is freed of other tendinous attachments around its circumference and denuded of all cartilage. The semilunar cartilages are removed and the anterior halves of both condyles of the femur

and tibia are also denuded, the crucial and lateral ligaments being left intact. A bed for the patella is then prepared by chiseling transverse grooves on the articular surfaces of the femur and tibia, and the patella is wedged into these grooves horizontally as the knee is extended. The severed ends of the patellar tendon are then sutured. (To facilitate the insertion of the patella in the grooves on the femur and tibia, with the knee at 160 degrees an anteromedial incision may be made and the quadriceps tendon lengthened by the Z-plastic method.)

After Treatment.—(See p 939)

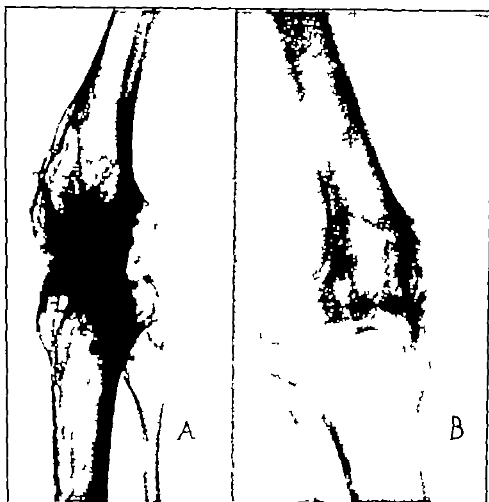


Fig. 635.—Fusions of knee joint by Hibbs technic. Case *A* ten months postoperatively Case *B* six months postoperatively

Technic (Galloway)—The knee is exposed through a U shaped incision, and the semilunar cartilages and all easily accessible tuberculous soft tissues are removed. A thin flap of bone is turned upward from the lateral surface of each condyle of the femur and a corresponding raw surface is formed on each side of the tibia. The ends of the femur and tibia are sawed off to form flat surfaces which appose accurately when the knee is in 165 degrees' flexion. The articular surface of the patella is removed with a saw and a corresponding raw surface is created on the anterior aspect of the tibia and femur All raw areas are precisely fitted together

Through a small incision on each side of the condyles of the tibia, two five-inch wire nails or Knowles pins are inserted through the tibia into the femur

in such position as to cross The patella is fixed across the joint anteriorly by two additional wire nails The medial and lateral flaps of bone from the condyles of the femur, which overlap the resected joint surfaces, are brought into accurate apposition with the denuded portion of the lateral aspect of the condyles of the tibia, thus providing additional grafts across the joint on both the medial and lateral aspects.

After Treatment.—(See p 939)

Technic (Henderson).—The knee joint is exposed through the U incision. The patella is freed of its tendinous attachments and saved in a sterile towel to be used as a graft. The synovial membrane including that of the supra patellar pouch is removed. The condyles of the femur and upper end of the tibia are sawed off squarely With the tibia displaced forward, the pathologic tissue in the posterior compartment of the joint is resected Additional bone is removed from the condyles to permit approximation at the desired angle of flexion the excised cancellous tissue, being osteogenic, should also be con served in a towel for future use. Through a small incision on each side of the midline of the leg, 12 cm below the upper end of the tibia two wire nails are driven through the tibia until their points are just visible above the excised upper surface. A flap of bone two centimeters in length is pried from the anterior margin of the upper end of the tibia, and a similar procedure is car ried out on the condylar portion of the femur With the raw surfaces of the tibia and femur in proper alignment and apposition, the nails are driven on into the femur Grafts from the patella or the excised cancellous bone from the tibia are inserted into the tibial and femoral flaps and the capsule is sutured over the flaps and closed as completely as possible

After Treatment.—(See p 939)

Henderson reports a series of 211 patients with tuberculosis of the knee, of whom 88.3 per cent obtained solid fusion by this procedure. The remaining 11.3 per cent of failures was reduced to 9.2 per cent by a second operation

Arthrodesis of the Knee With a Tibial Graft

Arthrodeses of the knee with the aid of tibial grafts are said to be ad vantageous in that normal bone which has not been in contact with the disease process is utilized. To be successful, the graft should extend across the joint to normal bone both above and below the knee. The additional incision which is required to remove the tibial graft is not necessarily a gross disad vantage if the graft is resected and the wound closed prior to incision into the knee the danger of contamination is negligible. Considerable time may be saved if the graft is removed from the opposite tibia while the knee is being prepared Every effort should be made to protect the tibial wound from contamination by the tuberculous infection of the knee This type of fusion should not be attempted in children, as the tibial graft will cause injury of the epiphyses and subsequent deformity or shortening

Brittain has advocated the use of two tibial grafts inserted in a cruciate fashion across the knee joint

Technic (Brittain).—The knee is exposed through an anteromedial approach the distal limb of the incision being prolonged down the crest of the tibia a distance of six inches Beginning just below the tibial tubercle, two five-inch parallel grafts, comprising the crest and adjacent portions of the tibia are removed with a motor saw The grafts are divided along the crest If desired the tibial portion of the incision may be closed before the knee joint is entered The patella is excised, and the articular surfaces of the tibia and

femur are removed with a twin bladed handsaw and wide thin-bladed osteotomes. Two special chisels or Henderson reamers are inserted through the tibial condyles from the anteromedial and anterolateral aspects, passing obliquely up through the femur, or one of the chisels may be introduced through the upper end of the tibial graft bed To prevent the graft beds from encountering each other the first chisel is left in place as the second is passed upward The first chisel is then removed and one of the tibial grafts is inserted in its track, the second chisel being left in place until the first graft is embedded. Care is taken to prevent separation of the femur from the tibia during the insertion of the graft. The second chisel is then extracted and the graft is inserted into its bed.

After Treatment.—(See p 939)

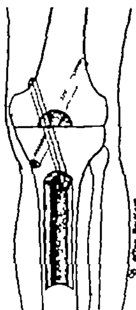


Fig. [illegible].—Brittain fusion of knee. (Adapted from Brittain, H. A. Architectural Principles in Arthrodesis, Edinburgh, 1942, E. & S. Livingstone.)

Technic (Putti) —The knee is exposed through an anteromedial incision and the patellar tendon detached. A triangular graft is removed from the upper anterior surface of the tibia, the apex of the graft being at a point just distal to the insertion of the patellar tendon on the anterior tibial crest and its base on the articular margin of the tibia A large osseous flap is then raised on the anterior surface of the femoral condyles, the graft is reversed, the apex driven beneath the osseous flap of the femur and the base apposed to the raw surface of the tibial condyle. The articular surface of the patella and a corresponding area on the femoral flap are next denuded and apposed. Two catgut sutures, one around the femoral flap and the other around the base of the transplant, temporarily stabilize the graft.

After Treatment.—(See p 939)

HIP

Numerous technics have been advanced for fusion of the hip joint, but herein will be described only those which represent fundamental principles.

Although the hip may be fused by either intra-articular intra and extra articular or extra articular methods, in our experience, extra-articular fusion is the procedure of choice when feasible By this technic, the capsule of the

joint is not incised and many disastrous complications are thus averted This advantage more than offsets the fact that solid osseous union may be slower and protection may be necessary for a longer time than following a combination of extra and intra articular procedures. In adults probably a more rapid fusion may be secured by the use of internal fixation For years, pins have been employed in the knee and recently, in the form of Smith Petersen nails for the hip, as suggested by Watson-Jones for non tuberculous lesions (p 1001) This type of fixation is not suitable for use in children.

Rarely in adults, wide resection of the hip joint may be necessary in connection with arthrodesis when it is obvious that resolution of the disease process cannot otherwise be anticipated Excision of the hip joint is practically never permissible in children.

Some degree of adduction and flexion contracture frequently follows fusion of the hip in children, regardless of the success of the operation in arresting the tuberculous process. In a large number of patients a subsequent subtrochanteric osteotomy is required when full growth is attained—a fact which should be explained to the family at the time of operation. Osteotomy is of little consequence however, if the tuberculous process is arrested by osseous fusion. After arthrodesis of the hip in the most serviceable position, the lumbar spine largely compensates for the ankylosis and often enables the patient to walk with only a slight limp

Pease recommends intrapelvic obturator neurectomy (p 1490) to prevent the adduction deformity which inevitably arises with growth. He has performed this operation in six children but sufficient time has not elapsed to permit an estimate of the final results He thinks that the incidence of both pseudarthrosis and deformity may possibly be reduced by section of the obturator nerve

The question of properly timing arthrodesis in tuberculosis of the hip in children is still a controversial one even the method of arthrodesis extra articular para-articular or combined intra and extra-articular is a matter of difference of opinion

McCarroll and Heath point out that it is rather difficult to obtain a good arthrodesis of a tuberculous hip while the disease is still in the active phase and that no one procedure is entirely satisfactory In view of the crippling effects of continued immobilization however they feel that early operative fixation is justified. The young child with a tuberculous hip is immobilized in a plaster spica for a period of approximately six months During this time his general condition is improved as much as possible by supportive measures At the end of the six months, if his general condition permits a Brittain type of arthrodesis is done or at least attempted or if this is not suitable some other type of extra articular fusion is performed. Thereafter, the patient is placed in a plaster spica for an additional six to twelve months. Even though the arthrodesis fails active use of the extremity is allowed at this time to obviate as much as possible any damage to the epiphyseal structures by prolonged fixation Later a second attempt at arthrodesis may be undertaken Pease feels that the combined intra articular and extra-articular fusion of the hip described by Chandler is preferable for eradicating tuberculosis of the hip joint in children Necrotic and tuberculous granulation tissue should be removed and excised as extensively as possible, thereby substituting healthy bone and producing a favorable site for new bone formation Of 28 fusions, union was secured in 25 Draining sinuses developed in four patients postoperatively and persisted for 2, 10 24 and 32 months respectively though fusion was firm in every case

In the discussion of the papers by McCarroll and Pease, both Gill and Barr did not think that fusion cures any tuberculous process, rather, that the defense mechanisms of the child has to do the curing and that it was not a good idea to operate on an active local infection Operation should be postponed until the patient is in good condition, all muscle spasm has disappeared, abscesses have regressed, and roentgenograms show no increase in bony destruction. Then, and then only though it be months or years, should operation be undertaken. We too in most instances, prefer the more conservative course. However, the disadvantages of late operation are well known perhaps, antibiotics may change our minds as regards early operation

It is obvious that no one operative technic can be suitable for arthrodesis of the hip in all the conditions and individual cases for which it is indicated not infrequently, a combination of technics is employed to meet the particular conditions found at operation.

If an active tuberculosis of the acetabulum or adjacent portions of the head and neck does not quiet down in a reasonable period of time the Brittain technic of fusion is preferred to long immobilizations, if the tuberculous process is at a low ebb and destruction does not progress the Chandler or Ghormley type of fusion is preferred.

Intra-Articular Arthrodesis of the Hip

Intra-articular arthrodesis is advisable principally in the presence of an extensive destructive process which remains stationary for a long period of time, and when necrotic tissue is so excessive that resolution cannot be expected following extra articular fusion. By this technic, the danger of relighting a virulent process is materially increased, and the prospect of securing solid fusion is less favorable than by other methods. The operation is more suitable for nontuberculous lesions, wherein the head and acetabulum are not extensively invaded In either case, one cannot depend upon fusion between the articular surfaces by simple denudation for, at best, the bony contact between the denuded head and acetabulum is insufficient the procedure should be supplemented by extra-articular grafts or bone flaps. Alone, this measure has been practically abandoned.

Technic—Either the lateral U (p 147) or the anterior iliofemoral approach (p 150) may be employed, preference being given the latter After exposure of the joint, all necrotic tissue and sequestra are removed. The cartilage is then excised from the head of the femur and the acetabulum down to cancellous bone and the osseous surfaces are approximated and thus maintained. Should necrosis be so widespread as to necessitate resection of the head and neck and a large portion of the acetabulum the trochanter is denuded and approximated to the raw surface of the acetabulum

After Treatment.—In adults, fixation at approximately 160 degrees flexion, 175 degrees abduction, and a position midway between internal and external rotation is most advantageous. In children, the hip should be placed in complete extension on a straight line with the body at approximately 170 degrees abduction and midway between internal and external rotation. Even in this position flexion and adduction tend to recur as growth continues. A plaster cast is applied from the nipple line to the toes on the affected side, and to just above the knee on the normal side. At eight weeks the cast is removed and roentgenographic studies are made of the hip If union is progressing satisfactorily the cast is replaced from the nipple line to the toes on the affected side, a wooden sole is attached a drop ring joint affixed at

the knee, and walking is permitted This cast is retained for two to three months, in adults, union may be solid at that time, although a longer period of immobilization usually is necessary In children, six to eight months of immobilization is required for solid union Four to six months postoperatively a leather lacer brace extending from the nipple line to the toes and reinforced by steel bars, is fitted and worn until osseous fusion is complete. Following removal of the brace, adults should be observed at intervals for one year, whereas children should be observed for several years, as deformity may develop from abnormal growth of the epiphyses and contracture of the powerful flexor and adductor muscles.

Extra-Articular Arthrodesis of the Hip Joint

Albee, in 1913, employed the following technic for extra articular fusion of the hip in tuberculosis. In 1919, he reported a substantial series of cases in which this was the method of treatment. Ankylosis is induced by bridging the area between the ilium and the trochanters with two cortical grafts from the tibia.

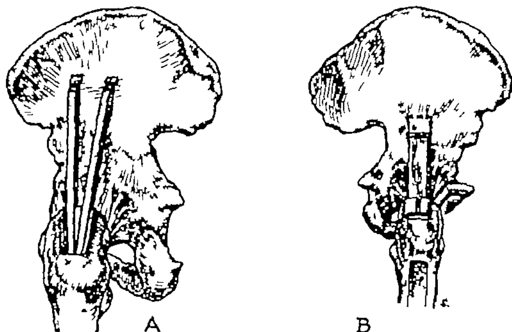


Fig. 437 —Extra-articular fusion of hip. *A* Albee technic. *B* Schumm technic.

Technic (Albee).—A semicircular incision, beginning one and one half inches posterior to the anterior superior spine, is carried forward to terminate one and one-half inches below the greater trochanter The fibers of the gluteal muscles are separated, exposing the trochanter and the side of the pelvis posterior to the anterior superior iliac spine. The trochanter is split vertically with a motor saw and flaps of bone are turned to the right and left by means of a broad osteotome Two indentations are made approximately two inches apart, in the lateral wall of the ilium midway between the iliac crest and the roof of the acetabulum the first indentation being one-half inch posterior to the anterior superior spine. A straight segment of cortex four to six inches in length, is removed from the tibia and split longitudinally with a motor saw forming two grafts. One end of each graft is beveled into wedge shape and these ends are driven into the indentations in the ilium The

opposite ends are implanted in the split trochanter and covered by the bone flaps, the latter being secured by a suture of chromic catgut. The fragmented particles obtained from shaping the ends of the grafts are placed about the pelvic and trochanteric extremities of the grafts.

After Treatment.—(See p 946)

Technic (Schumm).—The hip is approached through an incision beginning three inches directly posterior to the anterior superior spine of the ilium, curving downward and backward to the trochanter and extending distally seven inches on the lateral aspect of the femur The area just above the



Fig. 618.—Extra-articular fusion of hip for tuberculosis, seventeen months after operation.

acetabulum and the trochanter is exposed by blunt dissection of the gluteal muscles. A bone flap with periosteum intact is raised from the ilium, beginning three fourths inch above the rim of the acetabulum The flap should be three-fourths inch long and one fourth inch wide and its base should be upward. Osteoperiosteal flaps are turned back anteriorly and posteriorly from the center of the superior surface of the trochanter The distance from the trochanter to the flap on the ilium is measured. After exposing the lateral aspect of the upper third of the femur, a graft of suitable length and one-fourth the circumference of the bone in width is removed with a chisel and inserted into the flaps on the wing of the ilium and denuded surface of the

trochanter With heavy catgut the flaps of the trochanter are then sutured over the lateral portion of the graft and the wound is closed

After Treatment.—(See p 946)

Trumble fuses the hip joint by means of a graft which passes from the femur to a cleft in the tuberosity of the ischium The operation is therefore extra articular the graft being placed in normal tissue well outside the limits of the tuberculous process. Our experience with this procedure has been too limited to permit a true estimate of its value The results in a small number of cases have been disappointing

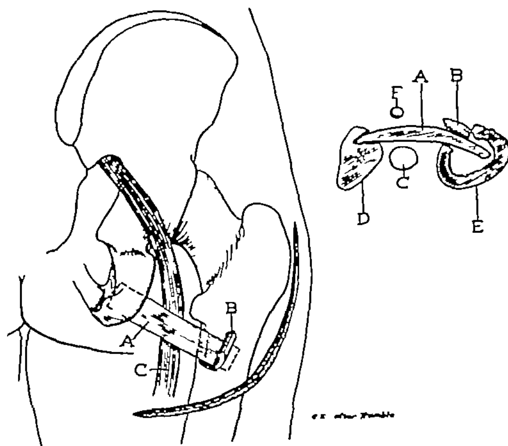


Fig. 439.—Extra-articular fusion of hip by graft extending from ischium to femur (Redrawn from Trumble, H. C. Australian & New Zealand J Surg. 1: 413 1932.)

Technic (Trumble) —The skin and fascia are incised longitudinally over the posterior aspect of the trochanter thence distally in a curve across the posterior aspect of the thigh to the midline below the level of the gluteal fold. After detachment of the gluteus maximus muscle with its osseous insertion, the musculocutaneous flap is elevated sufficiently to expose the tuberosity of the ischium, the femoral shaft and the sciatic nerve. With a chisel, a deep cleft is next formed in the tuberosity of the ischium. Likewise, a trap-door is created on the posterior medial aspect of the shaft of the femur just below the level of the lesser trochanter the lateral border of the door being hinged on the periosteum. A bone graft of proper length is then removed from the tibia and inserted into these clefts.

After Treatment.—(See p 946)

In 1941 Brittain described a method of extra articular arthrodesis of the hip based upon the principle of the subtrochanteric osteotomy wherein a broad tibial graft is inserted through the femoral osteotomy into a cleft in the ischium medially This method of arthrodesis embodies the principle that,

to insure stability and bone growth, compression is more efficient than tension. Atrophy of the soft parts on the medial aspect of the thigh incident to cast immobilization, places a strain on the iliofemoral graft which may predispose failure of the operation. By increasing the pressure however this same process makes the ischiofemoral arthrodesis site more secure. Moreover, progress of

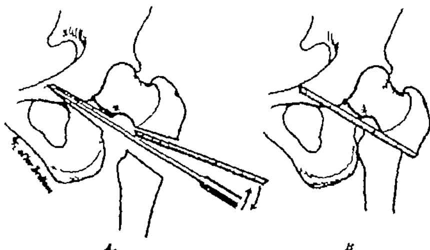


Fig. 640.—Brittain ischiofemoral arthrodesis. *A*, Osteotomy of femur has been completed and osteotome has been passed into ischium just below acetabulum, graft being inserted. *B*, Graft in place, femoral shaft has been displaced medially. (Adapted from Brittain, H. A. Architectural Principles in Arthrodesis. Edinburgh, 1942, E. & S. Livingstone.)

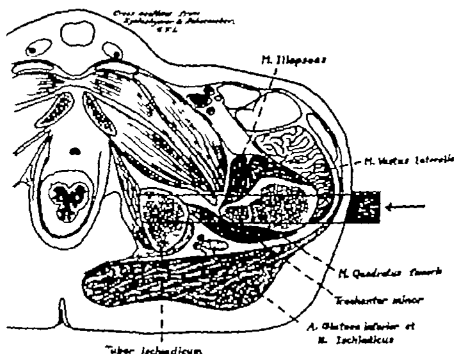


Fig. 641.—Brittain ischiofemoral arthrodesis. Cross section showing path of osteotomy and graft. (Adapted from Eycleshymer A. C., and Schoemaker D. M. New York, 1930, Appleton-Century-Crofts, Inc.)

the disease will not interfere with the ischiofemoral arthrodesis as it does with the iliofemoral type and further destruction of the head, with the consequent increase of dead space will not place an added strain upon the graft. This procedure has been used by Freiberg in obtaining fusion in a Charcot hip.

It should be borne in mind that, if the tuberculous process extends downward into the ischium the Brittain type of arthrodesis is contraindicated,

since the tibial graft must be inserted into a healthy bed It is also essential that the shaft of the femur be displaced medially until it lies in contact with the ischium The ideal situation is one wherein the upper end of the femoral shaft is displaced medially against the ischium and lies in contact with the tibial graft above Failure to approximate the femur and ischium necessitates arthrodesis across a dead space bridged by a graft and materially prolongs the period of postoperative immobilization

The following technic, which is used in this clinic, differs in minor details from that originally described by Brittain



Fig. 642.—A Tuberculosis of hip, primary in ilium. B Following Brittain ischiofemoral arthrodesis.

Technic (Brittain)—The patient is placed upon a fracture table as for the insertion of a Smith Petersen nail (Fig 80) The upper third of the femur is exposed by a lateral longitudinal incision (p 179) At a predetermined point, a guide pin is inserted into the lateral aspect of the femur the abductor ridge being utilized as a landmark. With a drill placed parallel to the floor and at an angle of 45 degrees to the shaft the pin is drilled until the ischium is penetrated one inch Roentgenograms are then made to verify its position A cortical graft of proper dimensions is next removed from the tibia and one end of the graft is beveled The femur is now osteotomized in line with the guide pin and the osteotome is continued in this plane until it penetrates both cortices of the ischium After removal of the guide pin, the osteotome is levered backward and forward to create a slot in the ischium With its endosteal portion distally the graft is inserted along the osteotome until the ischium is approximated. The osteotome is then withdrawn and the graft is driven into the ischium The soft tissues at the osteotomy site having been severed the distal fragment of the femur may be displaced medially by direct pressure and abduction. Prior to closure, check up roentgenograms are made.

If difficulty is encountered in maintaining the medial displacement of the shaft, the cast may be applied in sections, by this means, any valgus strain on the knee is obviated. Wide abduction may be necessary, though if so, the abducted position may be corrected after three weeks without loss of the medial position.

After Treatment.—(See p 946)

Intra-Articular and Extra-Articular Arthrodesis of the Hip

Ghormley coined the term, "para articular arthrodesis" to define those operations wherein the capsule is opened along the superior aspect, the head of the femur and acetabulum being undisturbed, in contrast to the ordinary intra-articular and extra-articular arthrodesis, wherein the head of the femur is dislocated from the acetabular cavity and the surfaces of the joint are widely resected. This term has been applied to a number of procedures which in reality are intra articular and extra-articular, in that the capsule is opened. Fusion is obtained by a graft or flap which is applied from above the acetabulum to the trochanter, and is placed in contact with the denuded surface of the neck of the femur

Any procedure which involves opening of the capsule is regarded as inadvisable by many surgeons because of the danger of disseminating infection. In Henderson's experience the operation has been followed by less drainage than any other He believes the method involves no more risk than extra articular fusion and is advantageous in that all pathologic tissue may be removed. Other advocates of combined intra-articular and extra-articular fusion are Sorrel, Eikenbary and Le Cocq and Berard

In 1922 Hass described a technic for intra articular and extra-articular fusion of the hip and reported the case of one patient so treated Hibbs, in 1926 reported the results of twenty fusions of the hip by a similar technic. Bristow points out that the Hibbs procedure, to be successful, must be executed with attention to detail. The bone graft, which should consist of the anterior two-thirds of the trochanter with about two inches of the cortical bone of the femoral shaft is pedunculated, the upper part of the trochanter being left attached by periosteum and the free end being taken from the femoral shaft. The free end is laid along the superior surface of the neck of the femur which has been bared for its reception and is firmly wedged into a groove cut in the ilium above the acetabular rim. Slight abduction then impacts the bone graft firmly into position.

Technic (Hibbs).—Beginning over the crest of the ilium two inches posterior to the anterior superior spine, the incision is carried down over the greater trochanter and extended for three inches along the shaft of the femur The deep fascia is split, the tensor fasciae femoris muscle retracted medially and the fibers of the gluteus medius and minimus muscles are separated by blunt dissection, exposing the capsule. The periosteum of the femur is incised along the base of the trochanter and retracted medially The anterior three-fourths of the trochanter with two inches of the cortex of the femur is completely detached with a chisel, leaving the muscle and periosteal attachments in situ. The capsule is split the superior aspect of the neck exposed and the cortex removed. A portion of the ilium, including the upper rim of the acetabulum is elevated without disturbing the muscles or periosteal attachments. The trochanter is now rotated and its lower end transposed beneath the elevated flap of the ilium its base fitting closely over the cancellous bone

of the neck The periosteum of the transposed bone is sutured to that of the iliac flap above and of the femur below The mass is also caught by the tip of the remaining one fourth of the trochanter, and thus, when the thigh is abducted 175 degrees and flexed 150 degrees, is held securely in place

After Treatment.—(See p 946)

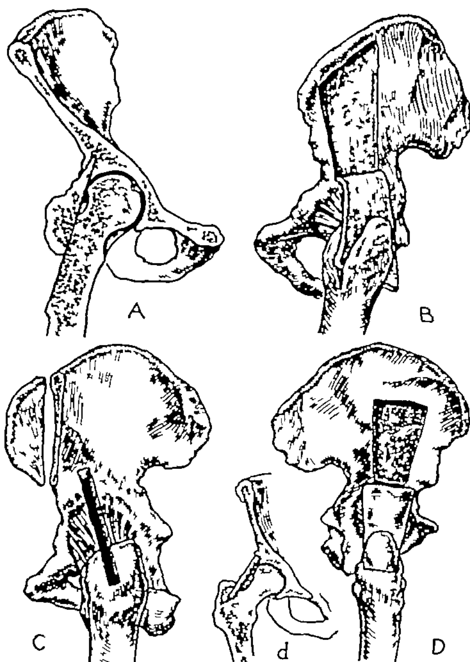


Fig. 441.—Intra-articular and extra-articular (para-articular) arthrodesis of hip. *A* Hibbs. *B* John C. Wilson. *C* Ghormley *D* Henderson.

Technic (John Wilson) —The capsule of the hip joint is exposed through a liberal anterolateral incision (p 146) In adults, the muscular attachments to the greater trochanter are freed with a blunt dissector In children, the epiphysis of the trochanter must be displaced laterally and posteriorly with the muscles, as nutrition of the bone flap will be endangered if its free end is implanted into a cartilaginous epiphysis. To aid in the preparation of the trochanteric cleft the shaft of the femur should be exposed for a distance of approximately two and one half inches. The joint capsule is split on its su

perior aspect, the anterior superior attachment to the ilium freed and well retracted The greater trochanter is then divided for a distance of two inches in the longitudinal axis of the femur With a thin osteotome, a fan-shaped section is reflected from the outer cortex of the ilium, the base of the fan just above the margin of the acetabulum being left attached By the exercise of a little caution, the pedicle may be bent and the flap turned into the trochanteric cleft This is accomplished without difficulty in young children, as the bone is flexible and not readily broken A greenstick fracture of the flap occurs occasionally the blood supply, however is not necessarily interrupted

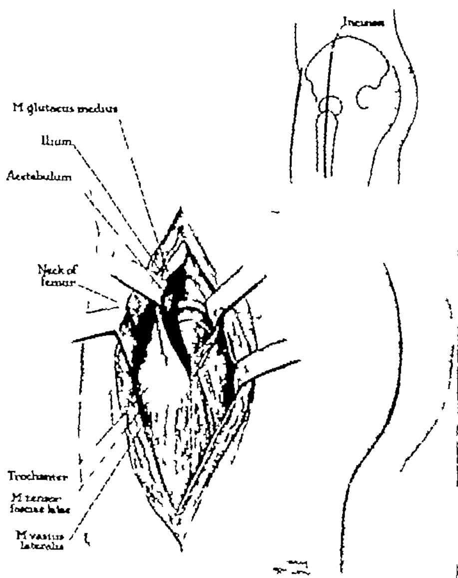


Fig. 644.—Chandler intra and extra-articular fusion of hip. Line of approach to joint, trochanter, and upper portion of shaft. (From Chandler F A.: J Bone & Joint Surg. 15: 947 1933.)

Since the periosteum of the ilium is removed with the gluteal muscles, replacement of the muscle flap brings the periosteum and fresh bone surfaces into contact. A solid pyramidal section of bone is thus obtained, the neck of the femur forming the base of the pyramid

After Treatment.—(See p 946)

Technic (Ghormley).—The incision begins on the crest of the ilium three and one-half inches posterior to the anterior superior spine, extends downward below the tip of the trochanter, then is curved forward to a point four to six inches below the anterior superior spine. The flap thus created is turned upward toward the midline. Exposure is effected by severing the muscular attachments to the wing of the ilium and stripping the gluteus medius and minimus muscles subperiosteally from the crest. A graft approximately three and one-half inches long, consisting of the crest of the ilium, including the anterior superior spine, is removed. The capsule is incised on the superior aspect from the acetabulum to the trochanter. A groove is then made from the upper rim of the acetabulum across the upper surface of the head and neck of the trochanter and the graft is beveled and impacted into the groove.

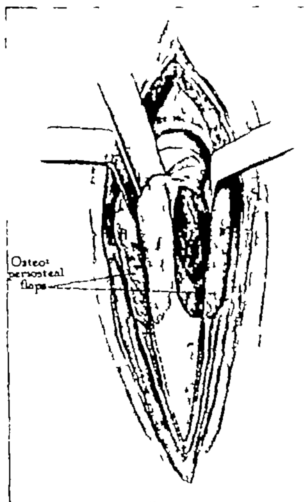


Fig. 645.—Same as Fig. 644. Method of removing graft. (From Chandler, F. A.: J. Bone & Joint Surg. 15: 947, 1933.)

Technic (Henderson).—The hip joint is approached through an incision similar to that used by Ghormley described above. The capsule is opened and the joint dislocated. All tuberculous tissue is removed and a sufficient amount of bone excised to permit approximation of the cancellous surfaces of the head and the roughened bone of the acetabulum. The hip is reduced and the superior surface of the neck denuded and freshened. A cleft of proper depth and width is formed in the trochanter and a graft from the wing of the ilium, of sufficient size to come into intimate contact with the neck of the femur and wall of the ilium, is inserted into the cleft. Small scrapings of spongy bone from the ilium are packed along the entire length of the graft.

After Treatment.—(See p. 946.)

Technic (Chandler).—The operative field is exposed through a longitudinal incision which extends from the crest of the ilium to the middle and upper thirds of the thigh (Fig. 644). The ilium above the hip is exposed by incision of the gluteus medius muscle in the line of its fibers. Bone flaps are raised anteriorly and posteriorly from the trochanter and base of the neck, the soft tissue attachments being left intact. A graft approximately five inches in length is next removed from the neck, trochanter, and upper third of the femur. To

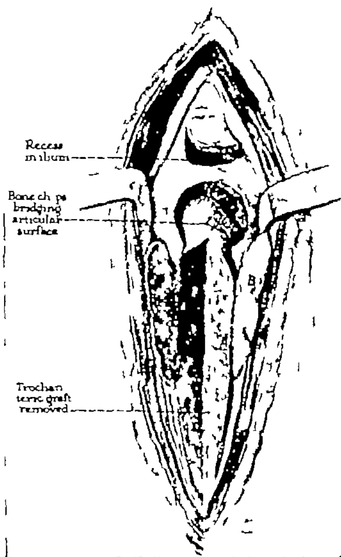


Fig. 645.—Same as Fig. 644. Superior joint surfaces denuded with a curved chisel. Bone chips packed into defect. Hinge flap of bone raised from ilium for reception of graft. (From Chandler, F. A.: J. Bone & Joint Surg. 15: 947, 1933.)

prepare the proximal end of the host area, the superior hip joint surfaces are denuded with a curved chisel. Cancellous bone is packed into this defect. A hinged flap of bone is now raised from the ilium just above the acetabulum and, with the hip in adduction, the cortical end of the graft is inserted into the recess thus created in the ilium; on abduction the graft should make maximum contact *with the neck and trochanter.* *The hinged osteoperiosteal trochanteric* flaps are sutured over the free end of the graft.

After Treatment.—(See p 946)

Badgley has devised a method for arthrodesis of the hip wherein a large iliac graft is inserted between the two tables of the ilium and into a gutter along the anterior aspect of the head and neck of the femur He advises its use particularly in patients over ten years of age

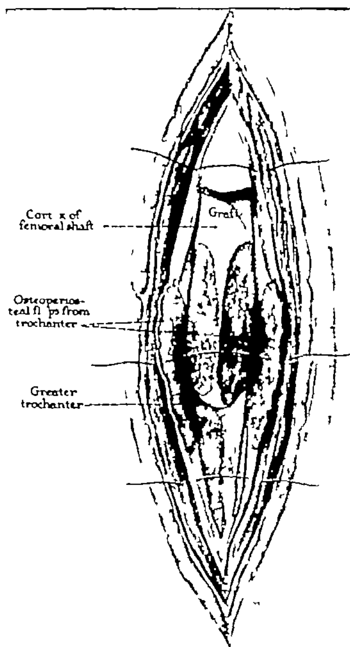


Fig. 647—Same as Fig. 644. Graft reversed and inserted into ilium, placed to make maximum contact with bone. Fixation maintained by suture of osteoperiosteal flaps. (From Chandler F A. J Bone & Joint Surg. 15: 947 1933)

Technic (Badgley)—An anterior iliofemoral approach is used the incision being extended well back along the crest of the ilium. The origin of the rectus femoris is detached and the psoas tendon is retracted medially A large curved graft, consisting of the anterior two-thirds of the spine of the ilium but not including the anterior inferior portion, is removed The anterior extremity of the ilium is now split down to the acetabular margin and the joint capsule is completely stripped from the anterior aspect of the head and neck of the femur If desired the cartilage may be removed from the acetabulum and

from the wing of the ilium and applying heavy traction to a Steinman pin inserted through the lower femoral metaphysis. With either type of traction, the extremity is gradually brought into a position of wide abduction, which in turn brings the greater trochanter adjacent to the acetabulum, permitting apposition of these two structures without difficulty at the time of arthrodesis

(2) Arthrodesis of the Hip in Wide Abduction —Through an anterior iliofemoral approach, the acetabulum and upper femoral shaft are exposed Scar tissue and cortical bone are removed from the upper and inner surfaces of the acetabulum and the superior, anterior, lateral, and posterior surfaces of the greater trochanter and upper femoral shaft, down to fresh cancellous bone The extremity is now placed in wide abduction, thus forcing the tip of the trochanter well within the prepared acetabular cavity and bringing the superior and lateral surfaces of the trochanter and upper femoral shaft in intimate contact with the superior and internal surfaces of the acetabulum. No attempt is made at this time to correct the position of the hip for weight bearing the only object is bony fusion.

The degree of abduction will vary with the individual, in some patients, 30 degrees may be sufficient, while in others, 70 to 90 degrees may be required for accurate fitting and wide apposition of the bony surfaces. The degree of abduction should be sufficient to place the apposed bony structures under firm compression.

(3) Correction of the Position of Wide Abduction by Osteotomy —Approximately two months after arthrodesis, the cast is bivalved and retained for immobilization following osteotomy After the patient is removed from the cast, the lower limb of the iliofemoral approach is reopened and the rectus femoris is retracted medially to expose the periosteum of the femur in the interval between this muscle and the vastus lateralis. Ligation of branches of the lateral femoral circumflex artery may be necessary at this point The periosteum is then incised and a transverse osteotomy performed just below the level of the lesser trochanter The wound is closed, and the bivalved plaster cast is reapplied and held in place with adhesive or a few turns of plaster bandage No attempt is made to change the position of the extremity

After Treatment —Two weeks following the last operation, the hip is examined and roentgenograms are made If clinical examination reveals some fixation of the fragments and the roentgenograms show beginning callus formation, the spica cast is removed, adhesive traction is applied to both legs, and a Thomas splint is placed on the affected extremity The affected extremity is held in abduction and traction is applied in this position, while the normal extremity is placed in traction in line with the trunk. Each day, the axis of traction on the affected extremity is changed, gradually decreasing the abduction, until the desired position is obtained. Flexion of the desired degree is secured by elevation of the lower end of the Thomas splint.

Ten days is usually required for bending of the callus. When the proper position is restored, the patient remains in traction until the osteotomy has firmly united. During this period, physical therapy with gentle motion to the knee of the affected side is begun. The position of the hip is checked at frequent intervals, both clinically and by roentgenographic examination.

For securing stability and permanent healing in old, "burned out" tuberculous disease of the hip with extensive destruction of the head and neck of the femur Bosworth has devised a method of "femoro-ischial transplantation." This procedure, of course may be utilized in residual destructive lesions of a nontuberculous nature Usually in hips of this type fusion has been attempted

femoral head, though without dislocation of the hip The hip having been placed in the desired position, a gutter is cut in the head and neck of the femur in line with the cleft between the tables of the ilium The graft is then wedged between the inner and outer tables of the ilium and countersunk into the trough or gutter in the femur, thus bridging the hip joint. If properly performed, this procedure provides firm fixation of the hip Accessory cancellous bone may be packed about the hip joint and the ends of the graft

After Treatment.—(See p 946)

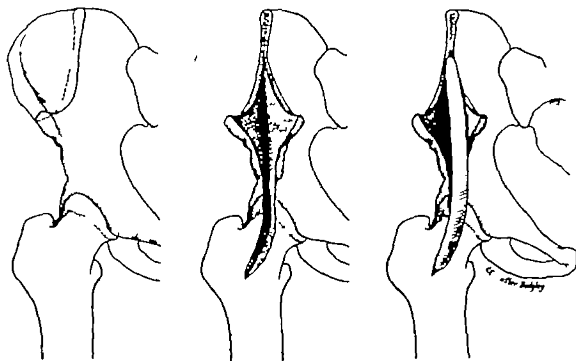


Fig. 648.—Badgley hip fusion.

Arthrodesis of Hip for Difficult and Unusual Cases

In the presence of extensive destruction of the head and neck of the femur, with or without dislocation, and in old unreduced hip *dislocations of adults*, fusion is notoriously difficult. The following procedures have been devised for such cases. They are also useful in many cases wherein the conventional fusion technic would not be adequate.

Iliotrochanteric Fusion

Abbott and Fischer have described a method of securing ankylosis following complete destruction of the head and neck of the femur and severe erosion of the acetabulum. The upper end of the femur represented by the greater trochanter may lie near the acetabulum or may be displaced upward on the wing of the ilium, in either position, it is usually fixed by scar tissue, cartilage, or bone. The operation is carried out in several stages (1) Correction of the deformity (2) arthrodesis of the hip in wide abduction and (3) reduction of the widely abducted position by subtrochanteric osteotomy

Technic (Abbott and Fischer).—(1) Correction of Deformity.—A moderate degree of deformity may generally be corrected by gradual stretching of the contracted flexor and adductor muscles by means of adhesive traction More severe deformities may be corrected by freeing the greater trochanter

from the wing of the ilium and applying heavy traction to a Steinman pin inserted through the lower femoral metaphysis With either type of traction the extremity is gradually brought into a position of wide abduction, which in turn brings the greater trochanter adjacent to the acetabulum, permitting apposition of these two structures without difficulty at the time of arthrodesis

(2) Arthrodesis of the Hip in Wide Abduction.—Through an anterior iliofemoral approach the acetabulum and upper femoral shaft are exposed. Scar tissue and cortical bone are removed from the upper and inner surfaces of the acetabulum and the superior, anterior lateral and posterior surfaces of the greater trochanter and upper femoral shaft, down to fresh cancellous bone. The extremity is now placed in wide abduction, thus forcing the tip of the trochanter well within the prepared acetabular cavity and bringing the superior and lateral surfaces of the trochanter and upper femoral shaft in intimate contact with the superior and internal surfaces of the acetabulum No attempt is made at this time to correct the position of the hip for weight bearing the only object is bony fusion.

The degree of abduction will vary with the individual in some patients, 30 degrees may be sufficient while in others 70 to 90 degrees may be required for accurate fitting and wide apposition of the bony surfaces The degree of abduction should be sufficient to place the apposed bony structures under firm compression.

(3) Correction of the Position of Wide Abduction by Osteotomy —Approximately two months after arthrodesis, the cast is bivalved and retained for immobilization following osteotomy After the patient is removed from the cast, the lower limb of the iliofemoral approach is reopened and the rectus femoris is retracted medially to expose the periosteum of the femur in the interval between this muscle and the vastus lateralis Ligation of branches of the lateral femoral circumflex artery may be necessary at this point. The periosteum is then incised and a transverse osteotomy performed just below the level of the lesser trochanter The wound is closed, and the bivalved plaster cast is reapplied and held in place with adhesive or a few turns of plaster bandage No attempt is made to change the position of the extremity

After Treatment—Two weeks following the last operation, the hip is examined and roentgenograms are made If clinical examination reveals some fixation of the fragments and the roentgenograms show beginning callus formation, the spica cast is removed adhesive traction is applied to both legs, and a Thomas splint is placed on the affected extremity The affected extremity is held in abduction and traction is applied in this position, while the normal extremity is placed in traction in line with the trunk. Each day, the axis of traction on the affected extremity is changed, gradually decreasing the abduction, until the desired position is obtained Flexion of the desired degree is secured by elevation of the lower end of the Thomas splint.

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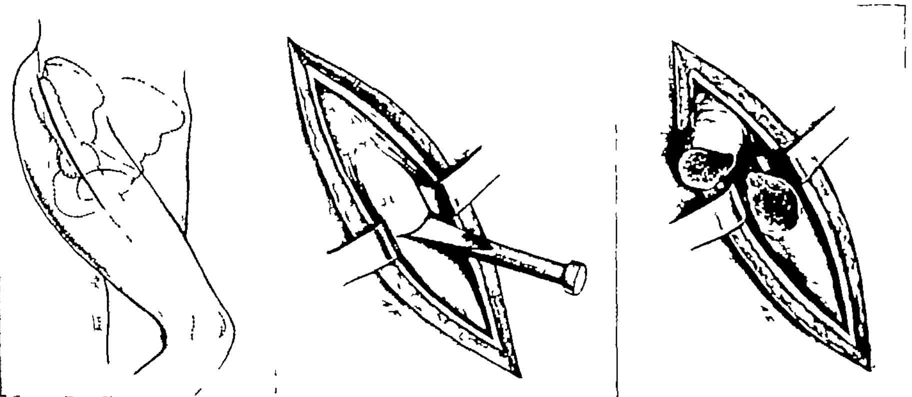


Fig. 649.—Bosworth "femoro-ischial transplantation. Lateral incision. Femur exposed subperiosteally and divided obliquely. Osteotome angled proximally and medially. Fragments retracted for exposure of ischium. (From Bosworth, David: J. Bone & Joint Surg. 24: 38, 1942.)

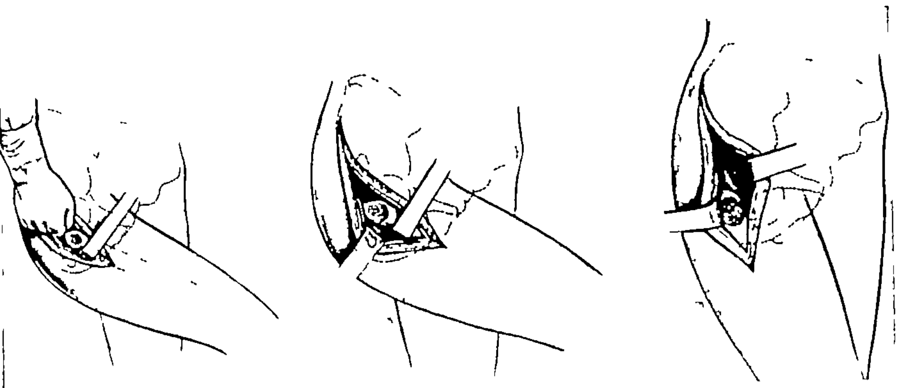


Fig. 650.—Same as Fig. 649. Location of ischium by palpation. Bony defect created in lateral surface of ischial tuberosity. Pointed end of femoral shaft buried in ischial defect. In final drawing, proximal fragment has been removed for illustrative purposes, but may be left in place. (From Bosworth, David: J Bone & Joint Surg. 24: 38, 1942.)

previously without success The method is also suitable for stabilization following Girdlestone's radical drainage of the hip (p 211)

Technic (Bosworth) —First Stage —In the presence of sinuses, a primary operation may be necessary in an effort to remove the diseased trochanteric portion of the femur, remnants of the neck fibrous tissue, and granulation tissue. This consists of an oblique section of the femur above the level of the ischial tuberosity, the portion of the distal fragment which points upward and inward, the trochanteric mass, and the fibrous and granulation tissue all being removed down to the fibrous tissue covering the old diseased area of the acetabulum and lateral surface of the ilium. If considered safe with the use of chemotherapeutic agents and antibiotic preparations, primary closure of the wound may be attempted, otherwise the wound may be treated by the method of Orr

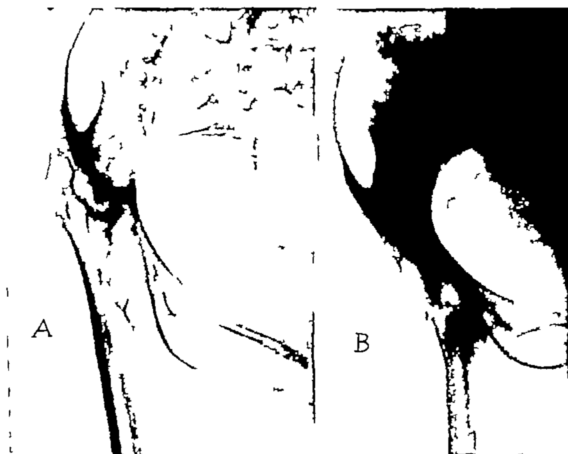


Fig. 451 —A Old burned-out tuberculosis of hip. Head and neck destroyed. B Two years after ischiofemoral fusion one and one-half inches in length regained.

Second Stage —The femoro-ischial transplantation itself may be carried out in one stage in all wounds without sinuses, and in others as well provided healing has followed the first stage.

A lateral incision is made from the trochanter well down on the femur through the fascia and vastus lateralis, and the periosteum is elevated from the femoral shaft opposite and just above the level of the tuberosity of the ischium. The shaft is then divided obliquely upward and inward, forming a point on the distal fragment Following retraction of the fragments of the femur the tuberosity of the ischium may be exposed on its distal and lateral surfaces by blunt dissection. Though the dissection of the ischium may be *visualized by retraction and extension of the exposure,* Bosworth generally

exposes the ischium blindly, and thus minimizes the dissection. After denudation of a suitable place in the tuberosity of the ischium, a cleft is made in the tuberosity with a large curette One must exercise judgment in selecting the site of the femoral osteotomy Some degree of length may usually be gained in all of these grossly shortened extremities If the osteotomy is placed high the tight fit of the femoral end in the tuberosity of the ischium, incident to the tension produced following implantation assists in providing stability and coaptation of the fragments The site having been prepared in the ischium the hip is flexed to approximately 90 degrees and a large bone skid is placed with its point in the ischial defect By extension of the thigh to about 150 degrees, strong tension is placed upon the musculature and fascia, thus forcing the end of the femur well into the prepared ischial defect (Fig 650) The periosteum and fibrous tissue which originally covered the denuded area of the ischium, then surround the end of the femoral shaft in a semicuff like manner

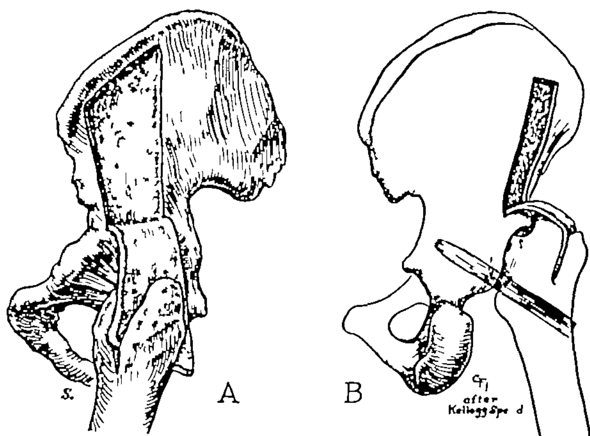


Fig. 652.—Arthrodesis of hip (Kellogg Speed) *A* Flap of ilium turned down after manner of Wilson iliofemoroplasty *B* Bone graft in place. (Adapted from Speed, Kellogg Surgery 1: 740 1937)

After Treatment.—(See p 946)

Kellogg Speed has described a method of hip fusion for a small group of adult patients with the following types of disability (1) Residual deformity with dislocation of the hip following suppurative coxitis or epiphysitis, (2) Painful subluxation or dislocation of the hip incident to trauma or disease, the dislocation having never been reduced or being irreducible except by operation Fracture of the acetabulum or femur may be associated (3) Congenital unilateral dislocation of the hip with extreme shortening wherein a stable hip is required, though a shelving operation is neither feasible nor desirable

dorsum of the ilium, and the erector spinae muscles are retracted toward the midline Beginning at the posterior spine and continuing around the crest of the ilium, a graft three fourths inch wide and three inches long is outlined by multiple cuts with a chisel, removed, and placed in a towel. The inner table of the overhanging portion of the ilium and the adjacent posterior surface of the sacrum are denuded Thus, a gutter of cancellous bone is formed by the posterior surface of the sacrum and the inner surface of the ilium posterior to and above the sacroiliac joint. Into this gutter is inserted the graft from the crest. The surrounding space is filled with multiple small grafts, or "shavings" from the dorsum of the ilium The mass of bone is then impacted with a blunt instrument, such as that designed by Joseph Freiberg (Fig 68) for this purpose

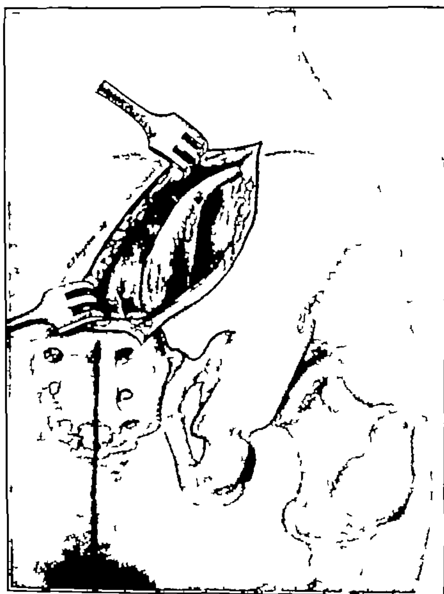


Fig. 653—Exposure for extra-articular arthrodesis of sacroiliac joint (Campbell)

After Treatment.—The patient is placed on a Bradford frame for a period of two weeks. The stitches are then removed and a cast is applied from the nipple line to the knees. Eight weeks postoperatively the patient is permitted to walk, supported by a long Taylor spine brace with sacroiliac attachments.

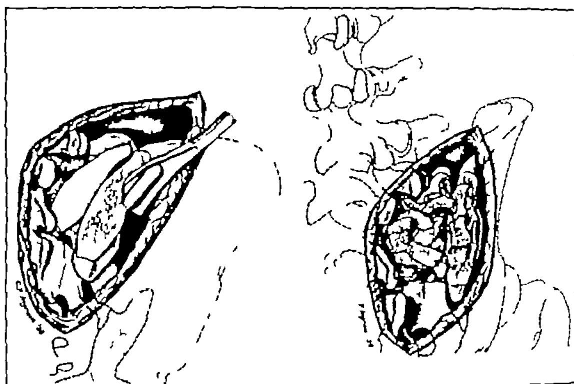


Fig. 654.—Inner table of ilium and adjacent posterior surface of sacrum denuded graft from ilium countersunk into this area. Multiple small bone grafts fill intervening spaces.

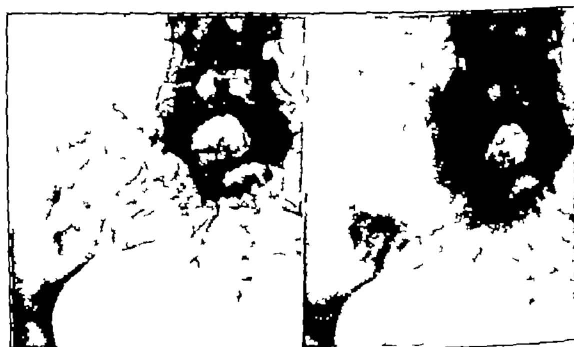


Fig. 655.—Tuberculosis of sacroiliac joint before and afte extra-articular fusion.

SPINE

Tuberculosis of the spine usually originates from a primary focus in the anterior portion of the body of a vertebra. The object of arthrodesis is to create a solid bony bridge between the posterior neural arches of the vertebral column. As the laminae and spinous processes are seldom involved the operation is entirely extra articular and does not expose the diseased area. Consequently, primary healing of the wound may be almost invariably anticipated

Since the majority of fusions of the spine for tuberculosis are performed on children, the question of growth disturbance arises, i e., whether fusion will stop the growth entirely or whether only the borders of the vertebrae will grow while the posterior portion remains stationary At the New York Orthopedic Hospital no differences were observed in the ultimate growth even following fusion in patients four five or six years of age Growth of the spine proceeded at a normal rate and the trunk leg ratio was normal with allowance for the effect of the kyphos.

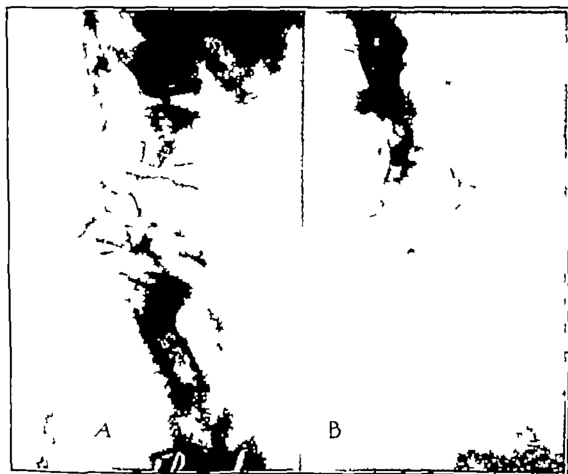


Fig. 6[illegible].—Albee bone-graft operation for tuberculosis of spine. *A* Case I Patient aged 6 years. Note calcified tuberculous abscess. *B* Case II, Patient aged 3 years.

As a rule two vertebrae above and below the affected vertebra or vertebrae are fused Van Otterloo maintains that fusion of such an extensive area is harmful is based upon a false principle and interferes with the natural correction of the spine in the formation of a compensatory lordosis below the area of fusion Further if the operation is carried out in the early stage of the disease, the graft interferes with the process of repair by impeding the natural physiologic collapse and the elimination of space between

the destroyed vertebrae He believes that by fusion of only the immediately involved vertebrae, collapse occurs normally and serves as a stimulus to bone formation. This is in contrast to Campbell's experience wherein satisfactory results have been secured by utilizing a massive graft which extends well above and below the affected vertebrae. As a rule, an increase in the kyphos and the compensatory lordosis is prevented if support is continued until the spine is solidly fused, the graft has hypertrophied and the bone has regenerated. In some cases, however this may not occur the kyphos may increase and the graft may break at the apex of the kyphos.

The operations for fusion of the spine are of two general types, based upon the principles originated by Albee and Hibbs in 1911 Prior to this time, attempts at internal fixation of the spine were unsuccessful. Hadra, of Galveston, in 1891, employed a figure-of-eight silver wire suture about the spinous processes, first for a fracture dislocation of the cervical spine, and later in the same year for Pott's disease Bick states that Calot, in 1897 was the first to attempt *fusion* of adjacent vertebrae for tuberculosis of the spine. Lange, in 1910 placed tin plated wire rods, bulbous at both ends, on each side of the spinous processes of the diseased vertebrae The rods were of adequate length to extend some distance above and below the affected vertebrae and were fastened in place by ligatures of silk inserted about and through the bone and around the rods.

In the Albee procedure fusion is accomplished by uniting the spinous processes into one continuous bony bridge by means of a graft transplanted from the tibia. In the Hibbs operation, fusion of the posterior neural arch is induced by overlapping numerous small osseous flaps from contiguous laminae, spinous processes, and articular facets. By combining the principles of these two methods and utilizing different types of grafts, a variety of technics have been evolved. Herein will be described those measures in most popular use

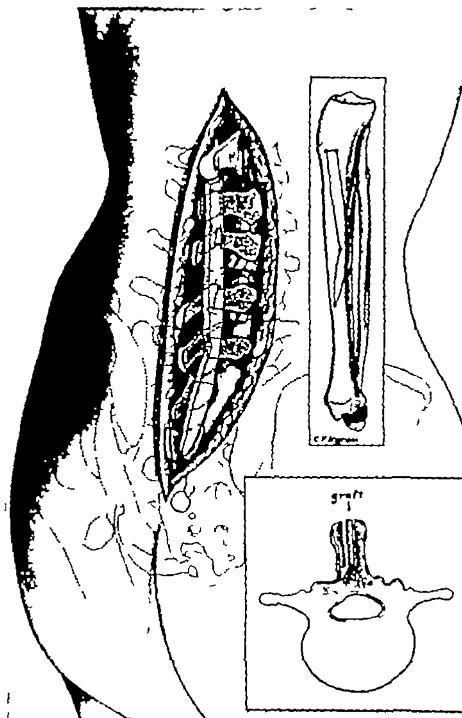
At operation, it is often difficult to identify with perfect accuracy the level of a given spinous process, particularly in the middle and lower dorsal and upper lumbar areas. In the cervical cervicodorsal dorsolumbar and lumbosacral regions, definite identification of a given vertebra is possible because of the anatomic peculiarities of the spinous processes, laminae and articular facets. In some conditions however the fusion area will be short and to place the fusion mass even one vertebra too high or too low would be undesirable for this reason, it is advisable at times to have marker films made before or at the time of the operation for definitely identifying a given spinous process within the proposed fusion area.

Marker films may be made by several methods. Preoperatively a narrow metal marker is laid transversely over a given spinous process, the skin marked with silver nitrate and a lateral roentgenogram is made localizing the process to the underlying vertebral bodies or in a sterile field the skin underlying the marker is scratched superficially with a scalpel transverse to the spinous process. According to another method, a hypodermic or skin needle is inserted into an underlying spinous process at operation, and the level ascertained by roentgenograms.

Albee Fusion of the Spine

Technic —Through a slightly curved incision on either side of the midline, the spinous processes of seven vertebrae three above and three below the affected vertebra, are exposed and the supraspinous and intraspinous liga

ments are divided longitudinally The spinous processes are almost down to the neural arches, and one-half of each is fr pletely at its base and displaced laterally The graft bed thus p sents a median longitudinal gutter A graft from the tibia, the f of the cortex in depth, three-eighths to one half inch in width an



length to cover at least two vertebrae above and below the site of the diseased vertebra, is removed with a motor saw and placed into the gutter The supraspinous ligament, muscles, and fascia are sutured over the graft.

This technic must be varied slightly for fusion of the lumbosacral spine. The spinous processes of the sacrum being too small to provide an adequate area of fusion a groove and flaps must be made into the posterior surface of the sacrum for reception of the graft and a curved massive graft cut to conform to the lordosis.

After Treatment.—As a rule the patient is placed on a Bradford frame. If however the spine is severely deformed as a result of vertebral destruction, anterior and posterior shells, previously prepared are more satisfactory in that the patient is unable to remain in the supine position on the Bradford frame with comfort. Moreover young children are more easily restrained in anterior and posterior shells, and postoperative care is less difficult.

The period of bed rest varies according to the nature of the disease which necessitated the fusion It should be remembered that fusion for tuberculosis is nothing more than an adjunct to conservative treatment, to enforce rest until healing takes place Thus, bed rest should be continued until healing of the tuberculous process itself, as well as complete consolidation of the fusion mass, is definitely evident Four to eighteen months may elapse following operation before walking may be allowed

According to Howorth the period of bed rest for a simple spinal fusion with the use of screws is two weeks otherwise, it is six weeks. He recommends three weeks in bed following removal of a herniated disc in conjunction with spinal fusion Following fusion with the use of screws for spondylolisthesis, he advocates rest in bed for six weeks, and without screws, for twelve weeks.

After the patient is allowed to be up a long Taylor spine brace is worn, and a fracture board with a firm mattress is used for rest in bed until osseous fusion is complete.

In the presence of moderate kyphosis, lordosis, or scoliosis, fusion by the use of a massive curved graft is most desirable In severe deformity this may not be possible and multiple thin flexible grafts or slivers of iliac bone may be necessary A massive straight graft cannot be made to conform to a curved surface A graft which is under considerable stress from continued destruction of the bodies of the vertebrae may disintegrate or fracture even after union apparently is solid and if under stress when inserted at operation may fail to unite

Technic for Obtaining Iliac Grafts.—(See p 130.)

Technic for Obtaining Straight Graft.—An incision two inches longer than the desired length of the graft is made over the anteromedial aspect of the tibia down to the bone. With a periosteal elevator, the soft structures are stripped from the anterior surface and the dimensions of the graft outlined on the bone with a chisel and mallet. Many surgeons leave the periosteum intact on the graft we do not believe this necessary The graft is removed by means of a motor saw During this process, sterile water should be dripped on the revolving saw blade constantly to keep the saw cool and prevent thermal damage to the bone Assistants should be cautioned to keep their fingers at a safe distance and *not to sponge while the saw is revolving* The periosteum should be carefully closed.

Technic for Obtaining Curved Graft.—The anterior surface of the tibia is exposed and the graft outlined by small holes drilled along the anteromedial aspect the apex of the curve including a portion of the medial border

of the tibia The graft is removed with a motor saw The crest must not be violated, as fractures may occur In this manner one may obtain a graft from six to eight inches long, which should fit an extensive lordosis in the lumbosacral region, or, when reversed, a kyphosis of the dorsal spine (Fig 657)

Technic for Obtaining Osteoperiosteal Graft (Ollier Delangenière) —An incision of the desired length is made over the mid portion of the tibia down to though not through, the deep fascia With a scalpel the deep fascia and periosteum are incised to the bone and the dimension of the graft outlined Following this outline an osteotome is driven one-eighth inch into the bone, the soft tissue attachments of the contemplated graft being undisturbed With a one-half inch chisel the osteoperiosteal graft is raised from one end by gentle blows of the mallet. Large, thin shavings of bone are then removed being held together by the fascia and periosteum This forms a flexible graft which may be fitted to a curved surface

Hibbs Fusion of the Spine

By the Hibbs technic fusion is attempted at four different points the laminae and articular processes on each side This procedure has been modified slightly over the years at the New York Orthopedic Hospital, it is at present performed as follows

Technic (Hibbs*) —The skin and subcutaneous tissues are incised in the midline along the spinous processes, and towels are applied to the skin edges with Michel clips. The deep fascia and supraspinous ligaments are divided in the line of the skin incision. With a Kermisson elevator the supraspinous ligament is removed from the tips of the spines. The periosteum is next stripped from the sides of the spines and the dorsal surface of the laminae with a curved elevator The interspinous ligaments are incised in the direction of their length making a continuous longitudinal exposure The muscles are then elevated from the ligamentum flavum and the fossa distal to the lateral articulation is exposed The fat pad in the fossa is excised with a scalpel or curette The spinous processes are thoroughly denuded of periosteum and ligament with elevator and curette split longitudinally and transversely with an osteotome, and removed with the Hibbs biting forceps The capsule of the lateral articulation is stripped away by means of a thick chisel elevator With a curette the posterior layer (about two-thirds) of the ligamentum flavum is freed from the margins of the distal and proximal laminae in succession and is peeled off the anterior layer the latter is left to cover the dura. The articular cartilage and cortical bone are excised from the lateral articulations with special thin osteotomes either straight or angled at 30 45 or 60 degrees, as required The preparation for the fusion is now complete

By means of a gouge, chips are cut from the fossa below each lateral articulation and turned into the gap left by the removal of the articular cartilage or a fragment of spinous process is inserted into the gap The fossa is well denuded of cortical bone and fully packed with chips Also with a gouge, chips are removed from the laminae and placed in the interlaminal space in contact with raw bone on each side Fragments from the spinous processes are used to bridge the laminae. Additional bone from the ilium near the posterior superior spine, or from the spinous processes beyond the fusion area is used Or bone from the bone bank may be employed especially if the bone available locally is scant because of spina bifida In the event the nucleus pulposus is to be removed the

* As described by Howorth.

chips are cut before exposure of the nucleus and kept until needed The remaining layer of ligamentum flavum is freed as a flap, with its base at the midline, retracted for exposure of the nerve root and nucleus and following removal of the nucleus is replaced for protection of the dura

After the chips are removed but before they are placed stainless steel screws may be inserted across the lateral articulations especially at the lumbosacral joints. A hole is drilled through the inferior and superior articular processes across the lateral articulation and into the pedicle. A screw three fourths to one inch in length is inserted into the hole fixing the bone transplant as well as the articulation

The periosteum ligaments and muscles are sutured snugly over the chips with interrupted sutures of chromic catgut the subcutaneous tissue with plain gut and the skin with silk or nylon

Hibbs Technic Supplemented by Osteoperiosteal Graft

Following the routine Hibbs operation, Lewin removes one or two osteoperiosteal grafts from the tibia and inserts them into the prepared bed, beside the spinous processes or along the laminae. These are added to promote osteogenesis, rather than fixation.

Modified Hibbs Technic Supplemented by Chip or Sliver Grafts

The following technic, developed by Henry and Geist, may be carried out rapidly and efficiently The operation is said to be suitable for patients of any age in children as well as adults an enormous bony ridge may be created across the neural arches. McKennon demonstrated by roentgenograms, which Campbell reviewed, a number of successful fusions of the spine in very young children secured by this method.

Technic (Henry and Geist).—Through a midline incision twelve inches in length seven or eight spinous processes are exposed and the soft tissues are dissected away from the processes and laminae With a hand chisel, small thin shavings of bone are gently removed from the laminae until raw cancellous tissue is visible The spines are clipped off at their bases, leaving the interspinous ligaments intact. As only five vertebrae are usually fused the spinous processes at each extremity of the wound are cut obliquely to preclude disfiguring projections.

As the bed is being prepared assistants remove from the tibia two handfuls of small chip grafts no larger than a finger nail. If time permits, the spinous processes are also cut into chips and utilized. The grafts are distributed up and down the graft bed and pressed into contact with the laminae and with each other

After Treatment.—The stitches are removed on the twelfth day and a closely fitting plaster jacket is applied on Goldthwait irons. Rest in bed should be continued for ten weeks following operation. The patient is then fitted with an axillary crutch brace of the Osgood type to be worn for three months.

Petter follows a technic similar to that described by Henry and Geist except that a section of a rib is removed and made into splinter grafts. He found that young children experienced considerable shock from trauma incident to removal of numerous grafts from the tibia.

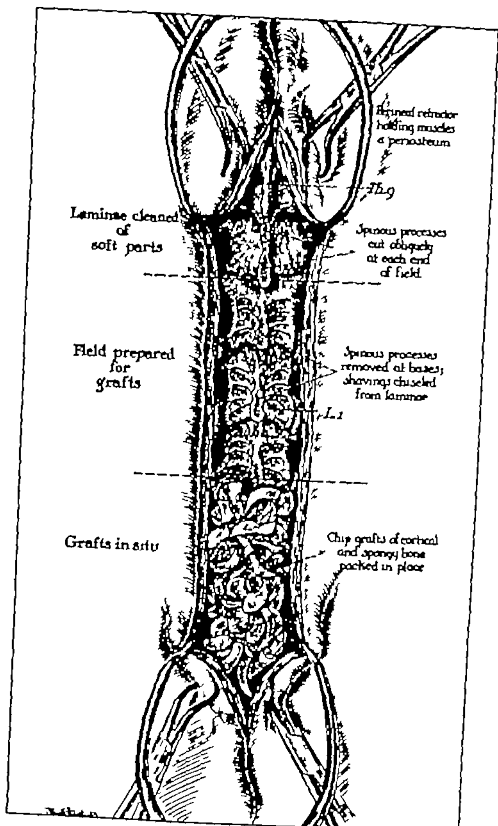


Fig. 659.—Henry and Geist technic of spine fusion. (From Henry, M. O., and Geist, E. S.: J. Bone & Joint Surg. 15: 612, 1933.)

Hibbs and Albee Fusions Combined

Ryerson has observed that the Hibbs procedure requires more time than is desirable and in patients whose osteogenic capacity is below normal, fusion may not take place, further that although the rapidity of the Albee technic is an obvious surgical advantage in many cases, the Albee tibial graft may be absorbed after months or years. He therefore combines the merits of the two as follows

After a reasonably accurate Hibbs subperiosteal denudation of only the laminae and spinous processes, one or more large grafts are laid on the small Hibbs grafts, or are inserted into the split spinous processes For fusion of the lumbosacral spine the grafts are removed from the iliac crests for fusion of the upper lumbar or dorsal spine, tibial or iliac grafts may be utilized

The Clothespin ("H" or Prop) Graft in Spinal Fusion

In 1931 Gibson in an attempt to obtain firmer fixation in fusion of the spine devised a tibial graft with clefts at each end which grasped the spinous processes of the proximal and distal ends of the fusion area the intervening spinous processes being resected Although he reported good results, little general use was made of this method until Bosworth described a similar procedure which he had developed independently for use in spondylolisthesis and laminal defects Early in Bosworth's work, an inclusion graft was employed because of its structural weakness however the clothespin ("H") graft was devised.

More recently Bosworth has employed a double clothespin graft from the ilium, with reinforcements by strips of cancellous bone This method is used only if one intervertebral space is to be crossed and separation of the vertebrae is not essential

Breck, Blount Regen Moore and others have used variations of the clothespin graft particularly in lumbosacral fusions. By flexion of the lumbosacral spine at the time of insertion of the graft it is possible to reduce the degree of lumbar lordosis to wedge open the lumbosacral joint restore the lumbosacral articular facets to a more normal relationship and to spread the intervertebral foramina

The clothespin graft consists essentially of a flat section of bone of proper length from the tibia or ilium with the ends notched to receive the spinous processes at each end of the fusion area The spine is flexed and the spinous processes are separated, either by breaking the operating table or by elevating the kidney rest and spreading the spinous processes apart with a vertebra spreader (Lewin) or by placing the patient in the lateral recumbent position (Moore) With the spine in flexion the graft is then inserted and is maintained firmly in position by extension of the spine

Moore has modified the technic of inserting the graft The patient is turned on his side, and his hips, knees, and lumbar spine are flexed, thereby spreading the lumbar spinous processes well apart this facilitates exposure and removal of the herniated intervertebral disc, reduces bleeding allows placement of the graft with greater ease and wedges the graft more securely in its bed when the spine is extended

If the spinous process of the sacrum is underdeveloped or absent the lower end of the graft is simply beveled to lie snugly in a bed on the dorsum of the sacrum In the presence of a spina bifida of one or more of the sacral segments the lower end of the tibial or iliac graft is fashioned as a double strut and placed in grooves cut transversely in the region of the articular facets of the first sacral vertebra.

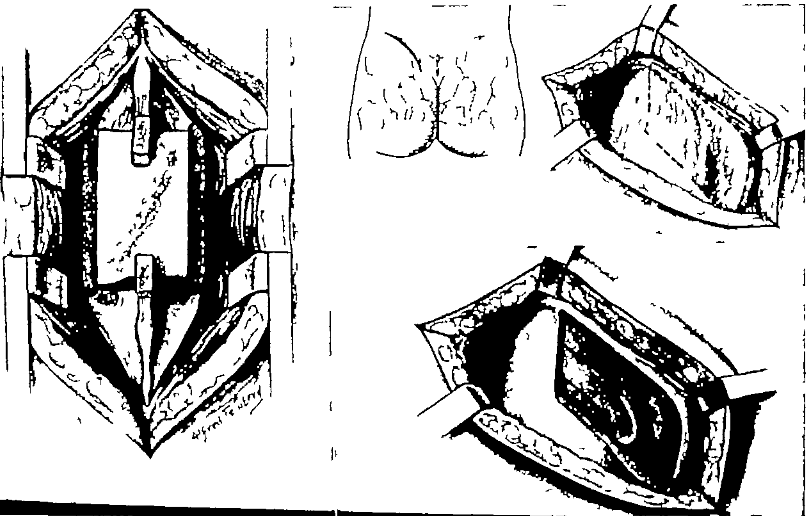


Fig. 660.—Lumbosacral fusion, with clothespin graft firmly seated between spinous processes of 1st sacral and 5th lumbar vertebrae. Graft fashioned from segment of posterior crest of ilium. Lower insert shows reinforcing cancellous iliac grafts. (From Bosworth, D. M.: Am. J. Surg. 67: 61, 1945.)

In fusing the spine by means of a clothespin graft, it is essential that the laminae be denuded of cortical bone and that cancellous bone be packed across the laminae and about the graft as in a Hibbs or modified Hibbs operation

Internal Fixation in Spinal Fusion

King in 1940 inserted metal screws across the articular facets following removal of the articular cartilage of these joints. The screws were designed to immobilize the joints during fusion thereby hastening fusion as well as reducing postoperative pain and disability Toumey Howorth and Baker have since verified the value of this adjunct to the usual fusion technic

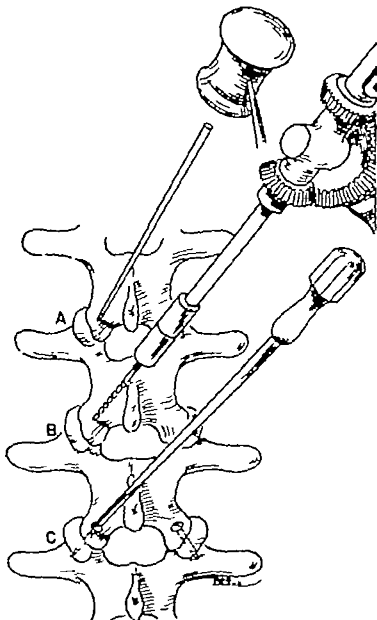


Fig. 661.—Technic of internal fixation of lateral articulations with metal screws. (From Baker L. D and Hoyt, Walter A., Jr South. M. J 41: 419 1948.)

Technic (King) —The spinous processes, laminae and articular facets are exposed subperiosteally in the routine manner and the cartilage of the articular facets is removed with an osteotome King recommends the use of a cautery to destroy any articular cartilage which may remain, while Toumey wedges small chips of bone in the defect produced by removal of the cartilage A hole is then drilled through the contiguous facets for the reception of the

screw an impression having first been made in the center of the facets by means of an awl or other pointed instrument to prevent the drill from wandering. The direction of the screw varies with the structure of the individual vertebrae and is readily determined by direct vision. Usually the drill is

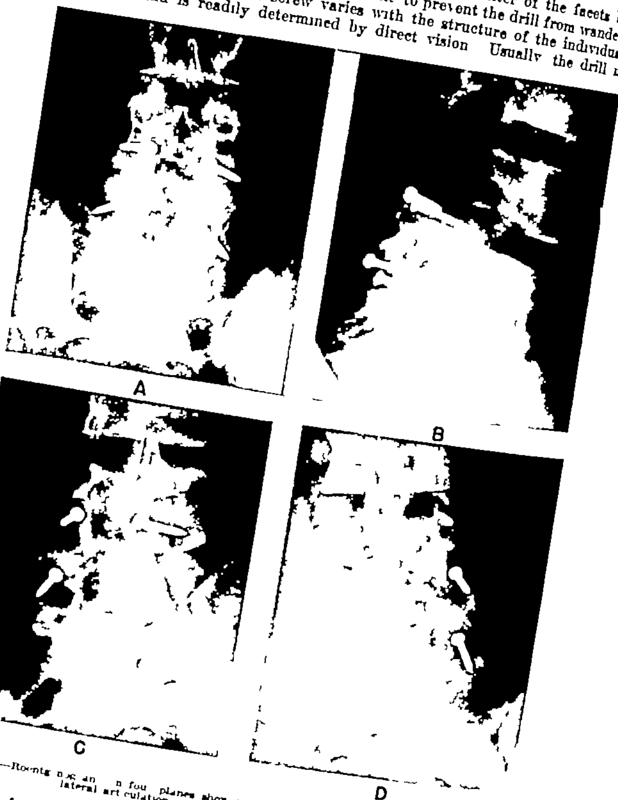


Fig. 662.—Roentgenograms in four planes show proper placement and alignment of screws in lateral articulation. (Courtesy of Dr Lenox D Baker.)

directed from 20 to 25 degrees caudally and 10 to 15 degrees laterally. For the average adult a screw three fourths inch in length is sufficient though for larger persons a one inch screw may be necessary.

two inches long is raised outward The clavicle and spine of the scapula are partially fractured in their distal thirds and angulated downward, permitting the acromion process and a portion of the clavicle to be wedged beneath the bone flap on the humerus when the arm is in abduction. If desired, bone chips or osteoperiosteal grafts from the tibia may supplement this procedure.

After Treatment —A shoulder spica cast is applied to the body and arm, *with the shoulder in an optimum position (p 1416) After eight to twelve weeks*, motion of the elbow and wrist may be instituted, although some form of support must be continued until osseous union is demonstrable.

Technic (Putti) —With the patient lying on the unaffected side, an incision is made from the medial or vertebral extremity of the spine of the scapula to the acromion, thence along the lateral aspect of the shoulder to the insertion of the deltoid muscle. The entire spine of the scapula is exposed subperiosteally the acromioclavicular joint being avoided With an

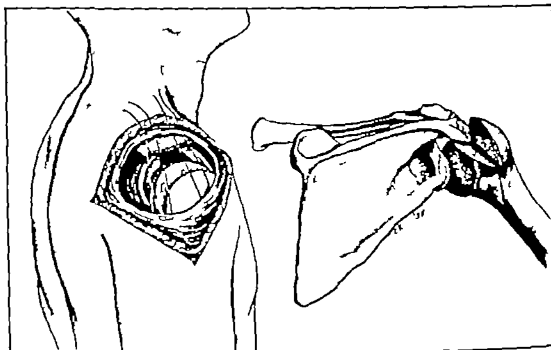


Fig. 664.—Gill fusion of shoulder (Redrawn from Gill, A. B. : J Bone & Joint Surg. 13 287 1931.)

osteotome, the spine of the scapula is detached from its base proceeding from the vertebral extremity toward the acromion The acromion is next divided along its dorsal margin into two sections, the medial layer remaining united to the scapula, while the lateral layer forms the distal portion of the transplant. The deltoid muscle is then incised in line with its fibers to expose the capsule and the upper two inches of the shaft of the humerus. The circumflex vessels are ligated and the nerve and vessels divided this results in paralysis of the deltoid muscle, which is not a serious complication in that the muscle is no longer required following fusion of the articulation. An osseous flap approximately one and one-fourth by three-fourths inches in size and including the entire cortex, is raised on the shaft of the humerus, with its base distally The shoulder is placed in 135 to 130 degrees abduction the distal extremity of the transplant is inserted into the opening in the humerus, and

the osseous flap flattened into contact with the outer surface of the transplant. The proximal extremity of the transplant is fixed to the raw surface of the acromion with several catgut sutures.

Brittain has described a technic of fusion of the shoulder by means of an extra-articular scapulohumeral graft The graft is placed between the medial aspect of the shaft of the humerus and the axillary border of the scapula thus any adduction of the shoulder compresses the graft in its long axis, making its position all the more secure In the usual extra-articular procedure wherein the acromion and humerus are approximated superior to the shoulder joint, adduction may distract or even separate the apposed denuded bony surfaces.

Technic (Brittain)—Two days before operation, a plaster cast is applied to the trunk though not to the affected shoulder or arm The tibial graft may be removed before the patient is placed in the prone position if a second operative team is available however the graft may be removed while the patient is in the prone position and the shoulder is being exposed The dimensions of the graft are as follows The point of the arrow is one inch long, the shaft is four to five inches long and one inch wide and the limbs are one inch long and one fourth inch wide and are separated by one fourth inch.

For the shoulder fusion the patient should be prone with sandbags or pillows beneath the chest to facilitate breathing and his affected arm should be allowed to hang over the edge of the table The shoulder is thus in a favorable position for arthrodesis and exposure is facilitated.

The incision which is approximately seven inches long is begun at the posterior margin of the deltoid carried up over the axilla and down the axillary border of the scapula to within one inch of its inferior angle The teres major and minor are identified the teres minor is incised down to the axillary border of the scapula and the latter is exposed subperiosteally If necessary the circumflex scapular artery may be divided and ligated. The interval between the long head of the triceps and the posterior border of the deltoid is now defined and widened. In the floor of the interval lies the lateral head of the triceps this is incised to expose the humeral shaft for a distance of two inches If the incision is prolonged too far proximally the posterior circumflex humeral artery may be severed. A large hole is next drilled in the humerus and widened with gouges until it is one-half inch in length and one inch in breadth. The distance which the graft must traverse is measured, and a suitable area on the axillary border of the scapula is selected for the notch With care to avoid fracture of the scapula a notch approximately one inch deep and three-eighths inch wide is now excavated The point of the arrow graft is then inserted into the humerus, the arm is abducted, and the graft is placed in position in the scapular notch If division of the long head of the triceps is found necessary this should be done above its nerve supply if possible Later the muscle is sutured into any convenient position though preferably over the graft The teres minor is sutured and the wound is closed Before the patient is moved from the operating table or is turned the plaster cast is completed, long reinforcements being placed on the arm and across the front and back of the chest

After Treatment.—(See p 980)

Intra-Articular and Extra-Articular Arthrodesis of the Shoulder

The following procedure was devised by Gill primarily for arthrodesis of nontuberculous affections of the shoulder By a slight modification however the technic may be entirely extra articular In the latter event no at

tempt should be made to fuse the humerus to the glenoid rather, fus should be attempted only between the extra articular portion of the humeru and the acromion or clavicle.

Technic (Gill) —A dorsolateral semicircular incision is made across th shoulder, beginning one half inch below the acromion At the midpoint o this incision, a vertical incision is carried downward for a distance of tw inches. After proper exposure the inferior and superior surfaces of th acromion are denuded leaving the periosteum intact proximally The head o the humerus and the glenoid are then divested of articular cartilage, the humeru is split longitudinally and a thin outer and anterior portion is reflecte

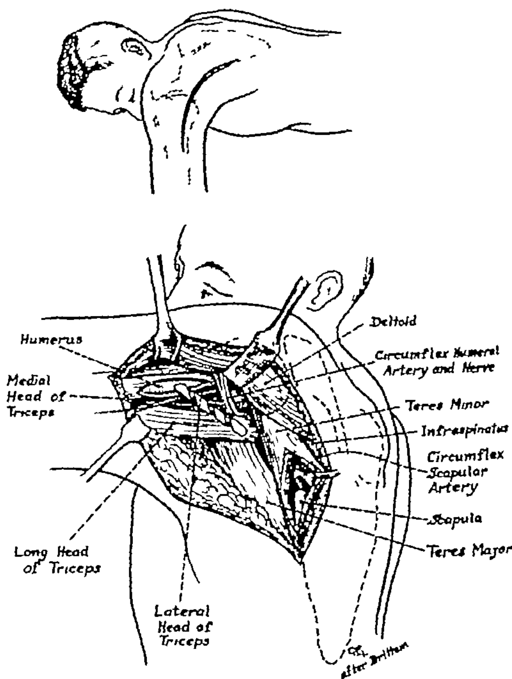


Fig. 685 —Brittain extra-articular fusion of shoulder by posterior method. Border o scapula notched through incision in teres minor muscle. Deltoid muscle retracted and medi head of triceps incised. Hole being drilled in humerus. (From Brittain, H. A. Architectur Principles in Arthrodesis, Edinburgh, 1942, E. & S. Livingstone.)

slightly outward A wedge of bone with its base upward is removed from the remaining portion of the head, forming a cleft into which the denuded acromion fits when the arm is in abduction The capsule, which remains attached to the reflected anterior and outer osseous flap, is sutured to the fascia and the periosteal flap on the superior surface of the acromion

After Treatment.—(See p 980)

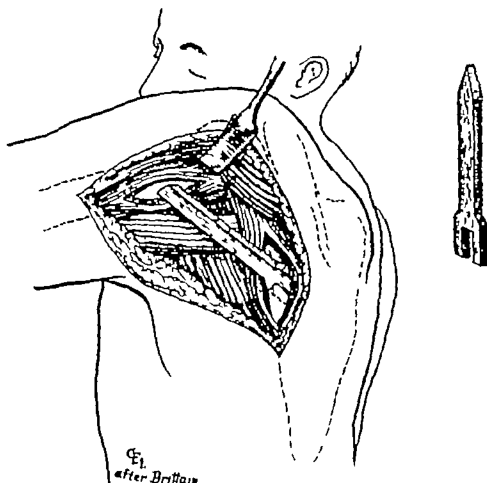


Fig. 666—Same as Fig. 665. Extra-articular arthrodesis of shoulder completed Insert shows detail of graft. Point of arrow has been inserted into humerus. Notched end of graft is dovetailed into notch in scapula. (From Brittain, H. A. Architectural Principles in Arthrodesis, Edinburgh, 1942, E. & S. Livingstone.)

ELBOW

The elbow is one of the most difficult joints in the body to fuse with any predictable degree of success Many technics of arthrodesis have been described, which is evidence in itself that no universally satisfactory method has been devised The indications for arthrodesis of the elbow are rarely encountered though the procedure may be employed in certain cases of chronic osteomyelitis with invasion of the elbow joint severe fractures followed by infection, and occasionally in tuberculosis At present however the consensus is that in the majority of cases resection of the elbow (p 916) is preferable to arthrodesis

In this joint because of its anatomic peculiarities a graft should be used when possible as a means of aiding fusion Also consideration must be given to the preservation of the radiohumeral joint a derangement of this joint may follow fusion of the ulnohumeral joint and excision of the head of the radius may be necessary to restore pronation and supination of the forearm

For unilateral arthrodesis of the elbow a position of 90 degrees is desirable whereas for bilateral arthrodesis, one elbow should be at 70 degrees in order to permit the patient to reach the mouth and the other should be at approximately 115 degrees These positions may be varied to meet the requirements of the patient s occupation.

Technic (Steindler) —The elbow is approached through a posterolateral incision extending from a point four inches above the elbow to a point one inch below the olecranon By means of a chisel the triceps tendon is dissected *from its insertion into the olecranon process The hypertrophied synovium is* excised as thoroughly as possible without removal of an excessive amount of soft tissue. The articular cartilage of the semilunar notch of the olecranon and the trochlear surface of the humerus is also excised the subchondral bone being fish-scaled. ' A graft one-half inch wide and three and one-half inches long is now removed from the upper portion of the tibia this is best done by a separate surgical team otherwise the graft should be removed before the diseased elbow is entered. A bed is next made in the posterior surface of the lower humerus for *reception of the graft, and a cleft is formed in the superior portion of the tip of* the olecranon With the elbow in flexion, the graft is fitted into the olecranon cleft then placed in its humeral bed as the elbow is extended to the position of fusion One or two metal screws are inserted through the graft into the humerus for fixation. The ulnohumeral joint may be packed with cancellous bone from the upper end of the tibia

After Treatment.—With the elbow at a right angle and in mid pronation and supination, a cast is applied from the axilla to the palm and bivalved to allow for postoperative swelling *After two weeks, the stitches are removed* and a new, snugly fitting cast is applied. Eight weeks postoperatively a leather lacer corset, extending from the upper arm to the head of the meta carpal bones and reinforced by steel bars, is fitted and worn until osseous union takes place

An extra articular fusion of the elbow which embraces the use of two tibial grafts, crossed in the shape of the letter X to lock the joint, has been suggested by Brittain No important anatomic structures are encountered in this procedure though one should take care that *the second graft,* which is introduced posteriorly does not project too far anteriorly He points out that considerable latitude is possible, in that, with the elbow in flexion the vessels and nerves in the cubital fossa are displaced forward.

Technic (Brittain) —The patient lies in the supine position with his arm resting on a sandbag on a small table, the elbow being at an angle of 90 degrees. Two grafts, three to four inches long and one-third inch wide are taken from the anteromedial surface of the tibia. A longitudinal incision five inches long is made over the posterior aspect of the elbow joint beginning directly over the olecranon and continuing upward through the triceps in the midline The incision is carried down to the bone throughout its extent. The ulnar nerve is exposed but not disturbed. Two holes, each one-eighth inch in diameter are drilled in the olecranon process one-half inch apart the first one fourth inch from the tip the second one-half inch distal thereto and are joined by an osteotomy These drill holes are necessary to prevent splitting of the bone. The osteotome is carried up through the elbow joint in the line of the shaft of the humerus though inclining slightly forward for a distance of three inches Two *similar holes are now drilled in the outer aspect of the* humerus just above the olecranon fossa While the first osteotome is retained in position, a second is introduced in the long axis of the shaft of the ulna and at a right angle to the humerus, but inclining slightly backward. By leaving the first osteotome in

position the second will avoid it and thus the grafts will not encounter each other in their passage through the bone The elbow joint will be completely locked by the two osteotomes. The first osteotome is now withdrawn and replaced by a slightly thicker chisel The latter is gently rocked to and fro, creating a space for the graft The graft is then introduced by bone forceps engaged for one inch or more, and driven into place The second graft is introduced in a similar manner

The bone may splinter to some extent in fitting the grafts tightly this, however, is controlled by the drill holes. But for the danger of splitting the bone both grafts might be introduced either from below through the olecranon, or from above through the humerus, thus necessitating a much smaller incision The grafts will undoubtedly splinter if this is attempted and in order to minimize the risk of such a contingency the larger exposure is well justified.

After Treatment.—See above

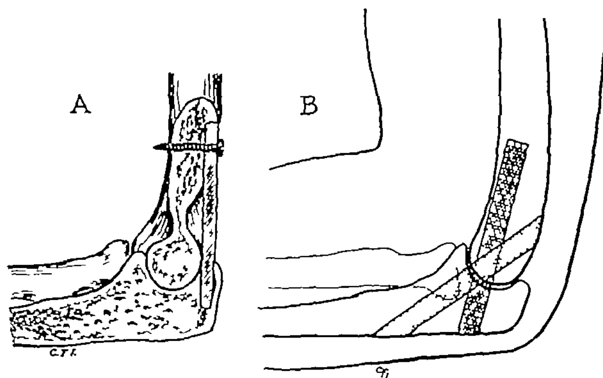


Fig 667.—*A* Arthrodesis of elbow with posterior cortical graft (Steindler) graft fixed to humerus with screw *B* Brittain arthrodesis of elbow by X cortical grafts placed to cross each other at center of joint, their breadth being in the position of greatest strain. (Fig. 667 *B* from Brittain, H. A. Architectural Principles in Arthrodesis, Edinburgh, 1942, E. & S. Livingstone.)

Gellman has devised a technic of arthrodesis of the elbow wherein a portion of the trochlea is utilized as a graft across the ulnohumeral joint. Bone from other sources is unnecessary further relatively uninvolved bone surfaces are brought into close contact Since the radiohumeral joint is not disturbed by the procedure rotation of the forearm is preserved The elbow joint may be placed at any desired angle without additional surgery

Technic (Gellman)—The inner aspect of the elbow is incised from two inches above to two inches below the tip of the medial epicondyle of the humerus The ulnar nerve is isolated and freed sufficiently to permit its retraction from the operative field The muscular attachments periosteum and capsule are stripped from the anterior medial, and posterior surfaces of the inner third of the lower humerus and from the inner and anterior surfaces of the upper end

of the ulna The inner third of the anterior portion of the exposed humerus, as well as its medial margin is then roughened by removal of a thin layer of cortical bone

Beginning at the top of the medial supracondylar ridge approximately the inner one-third of the lower humerus is separated by an osteotome flush with the humeral shaft and in its long axis (Fig 668) The graft having been freely loosened, a wire (A^1) is passed transversely through the epicondyle into the humerus to control this mass of bone. The graft is next rotated downward until it lies upon the surface of the ulna. An outline of the graft is now scratched upon the ulna (A^2) and the entire anterior cortex of the bone within the outlined triangular wedge (B^1) is removed. The humeral graft is again rotated downward and fitted snugly into this ulnar trough

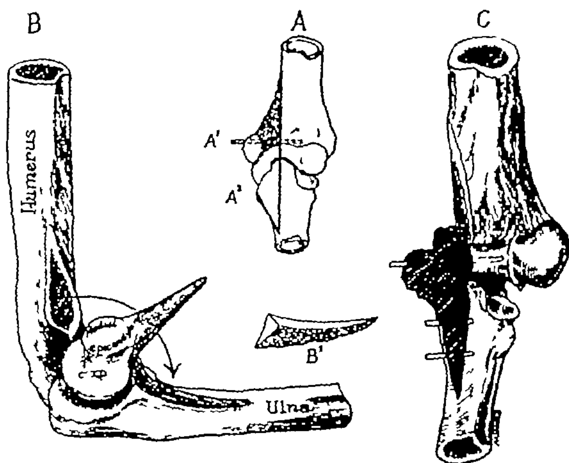


Fig. 668 —Gellman arthrodesis of elbow Medial one-third of lower humeral metaphysis separated by an osteotome. A wire (A 1) controls bone mass trough created in ulna by resection of bone (B 1) Graft rotated to fit snugly into ulnar trough, and fixed with wires, bone pegs or screws. (From Gellman, M. J Bone & Joint Surg. 29: 850 1947)

The desired position of the elbow having been determined, two additional wires or screws, or autogenous bone pegs made from the previously removed ulnar wedge are inserted through the ulna and the transplant to stabilize the graft The first humeral wire (A) may be removed at this point and replaced by a screw or a bone peg If advisable, the remainder of the triangular ulnar wedge may be converted into bone chips and packed into any crevices about the graft If under tension the ulnar nerve is transposed anteriorly The soft tissues are allowed to fall back into position and are securely sutured in layers

After Treatment —(See above)

WRIST

Fusion of the wrist is most often undertaken for tuberculosis, ununited or malunited fractures of the carpal scaphoid with associated radiocarpal traumatic arthritis, and severely comminuted fractures of the distal end of the radius, less commonly the procedure is carried out, in conjunction with tendon transplantations, for multiple nerve injuries of the upper extremity, Volkmann's ischemic paralysis and for stabilization of the wrist in infantile paralysis and in cerebral palsy of the spastic type

The wrist should be fused in the position which will preclude undue fatigue on use of the arm, and insure the maximum grasping strength in the hand This position is usually one of 160 degrees dorsiflexion, the long axis of the third metacarpal shaft being in alignment with the long axis of the radial shaft. *Clinically, it is determined by the position which the wrist normally assumes* with the fist strongly clinched Watson-Jones states that the thumb should be in line with the forearm when in opposition

Of the numerous technics which have been described, the majority includes the use of a bone graft of one type or another In some of these procedures, the graft bridges the distance from the radius only to the proximal carpal bones, whereas in others the joint is fused from the radius to the base of the third metacarpal Preservation of the intercarpal and carpometacarpal joints, if possible, is definitely advantageous, since some degree of motion will thus be retained in the wrist (Fig 426) Usually however the disease of the wrist joint extends into these joints, necessitating complete fusion. If arthrodesis is undertaken to relieve the pain and disability of a radiocarpal traumatic arthritis secondary to an ununited fracture of the carpal scaphoid or to a severely comminuted fracture of the distal end of the radius, fusion of the radius to the proximal carpal row may be attempted. In this event, damage to the joints between the proximal and distal carpal rows must be avoided at operation

The integrity of the distal radioulnar joint must likewise be preserved In the presence of a derangement or disease of this joint or a tuberculosis of the distal epiphysis of the ulna, the distal end of the ulna should be excised (p 597)

Since the distal radial epiphysis does not close until approximately the seventeenth year of age, care should be exercised in patients under this age. Following partial destruction of the plate by disease or trauma, however the remaining portion may be excised to prevent unequal growth. Fusion of the wrist in young children is difficult to secure because of the high cartilaginous content of the carpal bones and the radial epiphysis. When practicable, operations should preferably be postponed until the patient is 10 to 12 years of age

Abbott and his associates have described a method of arthrodesis of the wrist wherein flat cancellous grafts from the ilium bridge the denuded radiocarpal and carpal joints. To fix these grafts in place, their upper and lower ends are inserted beneath the bases of the bone flaps raised from the posterior aspect of the carpus and the distal end of the radius Personal experience with this method has proved it to be entirely satisfactory Abbott does not include the carpometacarpal joints in the fusion mass, believing that by leaving these joints intact, the metacarpal arch of the hand is maintained the power and strength of the grasp is preserved and the few degrees of motion remaining in these joints allow sufficient movement to absorb the shock of ordinary activity

By a somewhat similar technic, Colonna has utilized a portion of a rib as a graft in arthrodesis of the wrist since the natural curve of the inner half of the longitudinally split rib is of the proper degree to fit into the graft bed of the

wrist when the wrist is dorsiflexed to the optimum degree for function. The medullary cavity of the rib is closely approximated to the underlying denuded bone of the wrist joint, while the outer half of the rib is cut into small chips, to be packed between the denuded carpal bones in the wrist joint itself and about the bone graft. Colonna wedges the graft proximally into a cleft in the distal end of the radius, and distally into clefts elevated from the bases of the second and third metacarpal bones This procedure has been used in this clinic with success.

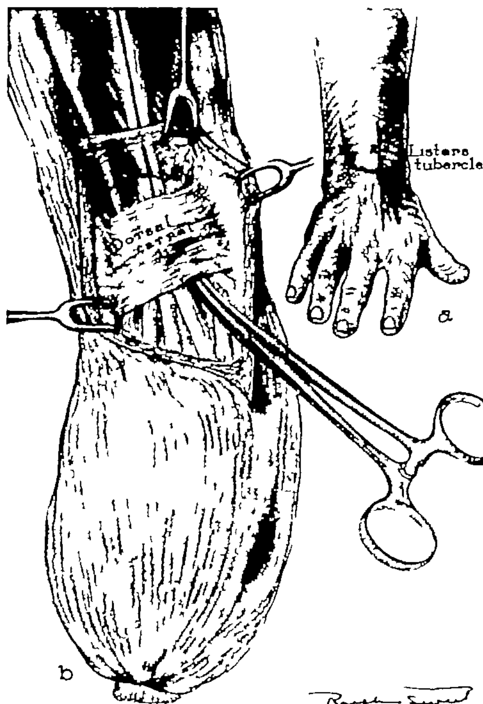


Fig. [illegible].—Arthrodesis of wrist (Abbott, Saunders, and Bost) a, Curvilinear or straight incision. b Exposure of dorsal carpal ligament. Hemostat indicates line of incision through ligament and periosteum on the lower end of radius. (From Abbott, L. C., et al. J Bone & Joint Surg. 24: 883 1942.)

Technic (Abbott, et al.)—Flat cancellous grafts are first removed from the anterior third of the crest of the ilium (p 130)

The wrist is exposed by a straight or preferably curvilinear incision centered over Lister s tubercle The dorsal carpal ligament and periosteum is incised over this bony prominence to the bone The radius is exposed by subperiosteal dissection the extensors carpi radialis longus and brevis, extensor pollicis longus, and the extensor digitorum communis being retracted to the radial and ulnar sides. After incising the radiocarpal ligament transversely at the distal margin of the radius, the articular cartilage is removed from the radiocarpal joint with a curved gouge The carpal joints are exposed by raising with an osteotome the capsule along with a thin section of cortex from the scaphoid semilunar and capitate bones In adults, an osseous flap is turned

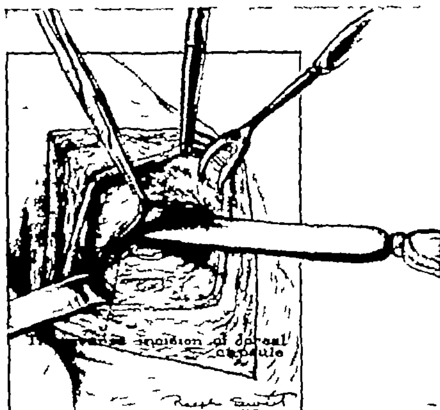


Fig. 670.—Same as Fig. 669 Radiocarpal joint opened through transverse incision. Beginning osteotomy of lower end of radius to create dorsal flap. (From Abbott, L. C., et al. J Bone & Joint Surg. 24: 883 1942.)

upward from the radius in children to avoid violating the epiphyseal line a horizontal cut is made in the articular surface of the radius for reception of the grafts. The cartilage between the scaphoid semilunar capitate and occasionally the lesser multangular bones is excised and the intervening spaces eradicated with cancellous chip grafts Broad pliable flat cancellous grafts are then placed on the dorsum of the carpus and radius, the ends of the grafts being tucked under the previously raised flaps Dorsiflexion stabilizes the transplants in place as the transverse incision through the capsule is closed with interrupted sutures.

After Treatment.—A cast is applied from the upper arm to the tips of the fingers and thumb with the elbow at a right angle the forearm in neutral posi

tion, and the wrist at 165 to 170 degrees' extension. The fingers and thumb are slightly flexed To allow for swelling the dorsum of the cast is windowed. Three weeks postoperatively a short cast (below elbow to just proximal to metacarpophalangeal joints) is applied checking the correct position of the wrist Support is continued until firm fusion is present, ordinarily, ten weeks.

Of 50 fusions carried out by this technic for a variety of conditions Abbott and associates report only one failure

Liebolt in a report on 44 cases of surgical fusion points out that in a relatively high percentage of cases of tuberculosis of the wrist joint the distal ulnar epiphysis is also involved. He bases this statement upon the finding of a developmental perforation of the triangular articular fibrocartilage of the ulna in approximately 30 per cent of anatomic dissections. He utilizes multiple small chip grafts from the distal end of the radius, or from the ilium or the tibia, rather than large 'bone slab grafts, believing that consolidation takes place more rapidly with the former

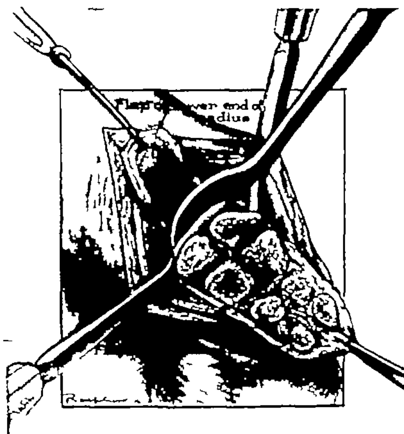


Fig. 471.—Same as Fig. 469 Osteoperiosteal flaps raised from radius and carpus to expose radiocarpal and intercarpal joints. Curved gouge used to remove cartilage from radiocarpal joint. (From Abbott, L. C., et al.: J Bone & Joint Surg. 24: 883 1942.)

Liebolt's technic for fusion of the wrist, though especially applicable to tuberculous joints, is also suitable in other conditions

Technic (Liebolt).—Through a dorsal longitudinal incision approximately three and one-half inches in length the dorsal carpal ligament is incised. The extensor pollicis longus and extensor carpi radialis brevis are retracted radially while the extensor indicis proprius and extensor digitorum communis are retracted toward the ulnar side The capsule is opened and the radiocarpal joint exposed

Generally only the involved joints are fused although better functional nd cosmetic results are obtained by fusion of the radius both rows of carpal ones, and the second third and fourth metacarpal bones

If diseased the distal end of the ulna is resected Removal of all the iseased tissue is unnecessary though all the cartilage other than that on the



Fig. 672.—Same as Fig. 669 *a* Chip grafts eradicate defects between denuded inter carpal and transverse intercarpal joints. *b* Cancellous iliac grafts bridge the joint. Ends of grafts are placed beneath flaps of radius and carpus. *c* Flaps approximated and transverse incision in capsule closed by mattress sutures. Superficial layer (dorsal carpal ligament) closed by mattress sutures. (From Abbott, L. C., et al. J Bone & Joint Surg. 24: 883 1942.)

anterior aspect should be removed from the joints to be fused. Destruction is often so extensive that removal of one or more carpal bones is necessary To preserve motion of the thumb particular care should be exercised not to enter the first carpometacarpal joint if this joint is diseased resection is preferable to fusion

An adequate number of bone chips are placed in all spaces created by destruction of bone, as well as between the various bones to be fused, and especially over the dorsum of the radionavicular joint

In an effort to prevent sinus formation and adhesions of the extensor tendons, the wound should be completely closed Because of the danger of wound disruption interrupted sutures should be used

After Treatment.—See above

For many years, Gill has employed the following method of arthrodesis of the wrist, with uniform success. In this procedure, the graft is removed from the dorsal aspect of the distal end of the radius.

Technic (Gill)—A straight longitudinal mid-dorsal incision is made from a point three to four inches proximal to the wrist joint, to a point one and one-half inches distal thereto The dorsal ligaments and joint capsule are incised longitudinally and freed by subperiosteal dissection from the carpal bones and the lower end of the radius.

The articular cartilages of the radius and the proximal carpal bones are then removed A plate of bone, two and one-half inches long and comprising the full width of the radius, is removed from the dorsal aspect of the lower end of the radius. At its distal end the plate should be about one-fourth inch thick, and at its proximal end one-half this thickness also its center should be thicker than its lateral margins. Thus, because of the shape of the radius, the graft is *narrower and thinner proximally than distally*

The wrist is now placed in the desired position for arthrodesis, and a broad, thin osteotome is laid flat on the dorsal surface of the radius and driven into the proximal carpal bones, or even through these bones into the distal row The proximal wedgelike end of the bone graft is then driven firmly into the carpal cleft the remaining portion fits snugly into the gutter in the radius, maintaining the proper position of the wrist. Bone chips from the radius may be inserted into defects in the joint The capsule ligaments, and periosteum are sutured over the graft.

Smith Petersen in conjunction with many other useful procedures for atrophic arthritis of the upper extremity reported an arthrodesis of the wrist, suggested by the exposure of the wrist after resection of the distal end of the ulna. This technic, of course, should not be used unless there is disease or derangement of the distal radio-ulnar joint.

Technic (Smith Petersen).—The skin is incised longitudinally for two and one-half inches just above and parallel to the distal end of the ulna, *thence* anteriorly toward the base of fifth metacarpal bone. After subperiosteal exposure, the distal inch of the ulna is resected. The periosteum and capsule are incised and dissection continued, exposing the ulnar aspect of the distal segment of the radius, the radiocarpal joint and the carpus. A slot is then created for reception of a graft fashioned from the resected portion of the ulna. The remnants of the ulnar segment are packed in as supplementary grafts.

After Treatment.—See above

Brittain has devised a method for arthrodesis of the wrist, wherein a bail type graft is employed and the step-cut ends of the graft are dovetailed into the ends of the graft bed. The chief objection to this procedure is that arthrodesis

of the wrist in the proper degree of dorsiflexion for optimal function of the hand is difficult by the use of a straight graft

Technic (Brittain).—The dorsal aspect of the wrist is incised longitudinally, beginning about three and one half inches above the lower end of the radius and extending to a point one inch distal to the base of the third metacarpal bone. The tendons of the extensor digitorum communis are retracted to the ulnar side and the tendon of the extensor pollicis longus is retracted to the radial side. One may attempt to save Lister's tubercle in order that the tendon pulley may be preserved though this is usually impossible

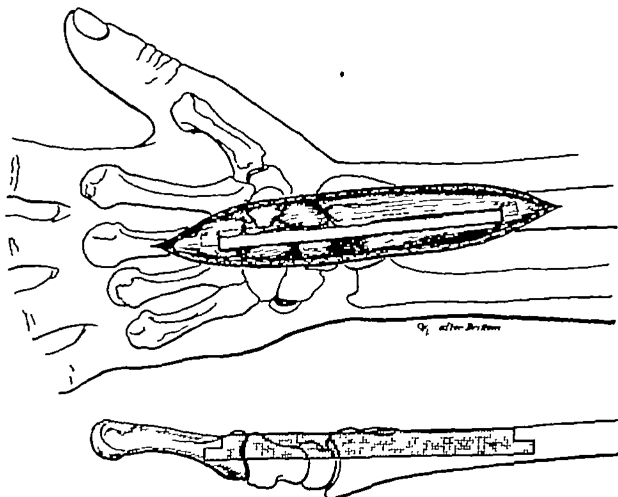


Fig. 673.—Arthrodesis of wrist (Brittain) with tibial graft. Insert shows graft placed in medullary portion of radius and into base of third metacarpal bone. Graft traverses carpus without regard for identity of bones. (From Brittain, H. A. Architectural Principles in Arthrodesis, Edinburgh, 1942, E. & S. Livingstone.)

With a motor saw a bed is cut for the bone graft beginning at the proximal third of the third metacarpal bone and continuing to a point two inches proximal to the distal end of the radius. The bed which should be a little less than one half inch in width, should be cut from the carpal bones without respect to their identity. Brittain advises that the cartilaginous covering of the bones should be left undisturbed, with the exception of that part which is removed in making the graft bed. A small chisel is next introduced into each end of the bed to open the medullary cavity for a short distance. A graft one-half inch in width and one half inch longer than the prepared bed is now cut from the tibia and introduced into the radius for a distance of one fourth inch. Traction is then exerted on the fingers, that the other end of the graft may be levered and dove

tailed into its bed in the third metacarpal bone. On release of the traction the metacarpal bone should overlap the graft and hold it securely, the step in the graft fitting beneath the undercut portion of the bed at each end

After Treatment.—(See p 989)

ARTHRODESIS OF NONTUBERCULOUS JOINTS

The majority of operations for fusion have been described in the section on Arthrodesis of Tuberculous Joints, although they may be applied to nontuberculous affections as well In the latter the joint may be entered with impunity hence the extra articular technics are usually supplemented by intra articular arthrodesis. Several of the operations described herein were originally devised and are still used for the treatment of tuberculous lesions in our opinion however they are more suitable for lesions of other types in that the technics are both intra-articular and extra articular

ANKLE

Anterior Arthrodesis

In the presence of incongruous or irregular surfaces of the ankle of non tuberculous origin, an attempt should be made to preserve the subastragalar joint by fusion of the astragalus to the tibia only

The success of ankle fusion depends upon whether the foot is fixed in the proper position Fusion in calcaneus will result in a stiff peg leg gait from lack of push-off ' while too much equinus will produce a halting gait wherein the *stance phase is not completed The foot is kept in front of the body* and walking is accomplished in short steps, the arthrodesed foot being pushed ahead and the opposite foot being brought up from the rear If the ankle is arthrodesed at a right angle however and provided the gait is not affected by any other deformity of the extremity the patient can walk with no perceptible limp In women since the ankle is fused in slight equinus the gait is usually poor on walking barefoot, whereas with shoes it is excellent

The foot which is stabilized prior to or at the time of ankle fusion (p 1320) will have less forefoot mobility than one wherein the ankle alone is fused Thus, if the foot has normal joint mobility and muscle balance, it has been found that, in males, an ankle fused at 90 degrees will have better function than one in an equinus position midtarsal motion will allow sufficient drop of the forefoot to compensate for heel height and the added range of dorsiflexion will afford a more elastic gait. In women a position of 95 to 100 degrees at the ankle will permit shoes with a relatively high heel to be worn, while low heeled shoes may be worn with comfort and a good gait, and the barefoot gait will be fairly satisfactory

Technic.—A longitudinal incision is begun approximately four inches above the ankle joint and one inch medial to the fibula, continued downward over the lateral aspect of the joint, and terminated at the external cuneiform bone (p 137) The superficial and deep structures are incised exposing the lower third of the tibia and ankle joint. With a chisel, the entire articular cartilage of the astragalus, tibia, and fibula is cut away together with sufficient bone to provide an unobstructed view of the ankle joint. Extreme equinus deformity may be corrected through a separate incision by lengthening of the tendo achillis and posterior capsulotomy (p 1021) This is rarely neces-

sary, as satisfactory correction of the equinus is usually possible after resection of the articular surfaces. Further slight equinus is desirable following fusion of the ankle. Medial or lateral deviation of the astragalus on the tibia may be corrected by removal of a larger portion of bone from the inner or outer aspect of the astragalus or tibia. This intra-articular arthrodesis should then always be supplemented by the use of one of two types of graft: (1) sliding inlay or (2) transplanted inlay graft, the former being preferable.

(1) A full thickness cortical graft one inch wide and two inches long is removed from the tibia immediately above the joint surface. A gutter of suitable dimensions is cut from the anterior portion of the body and the superior surface of the neck of the astragalus. With the astragalus and articular surface of the tibia in proper alignment the sliding graft from the tibia is moved down across the anterior surface of the joint and its lower half is countersunk into the gutter of the astragalus.

(2) The cortical graft is removed from another portion of the tibia and placed into a window of equal dimensions cut in the anterior aspect of the tibia and astragalus. The graft should be so placed that dorsiflexion will be blocked at the proper angle for walking.

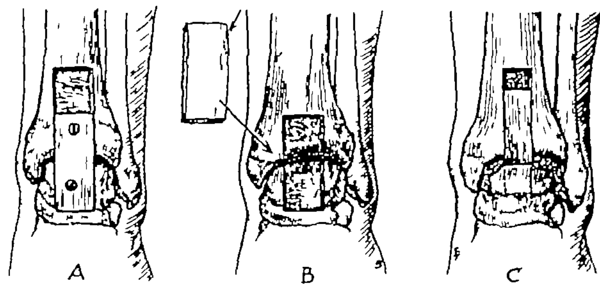


Fig. 674.—Anterior fusion of ankle. *A*, Sliding graft fixed with metal screw. *B*, Graft of same dimensions as prepared bed, removed from upper portion of tibia. *C*, Sliding graft inserted in cleft in astragalus, accessory chips in place.

To insure early and more certain fusion, prevent displacement of the graft and maintain the optimum position, metal screws may be inserted through the graft into the tibia and astragalus. Cancellous or cortical splinter grafts should be used to fill any dead space between the malleoli and the body of the astragalus.

After Treatment.—In order to press the denuded articular surfaces of the astragalus into the mortise of the ankle, the knee is flexed to a right angle and the leg is tightly wrapped lengthwise with flannel bandages from beneath the heel and longitudinal arch to above the knee. Padding is supplied by circular bandages. The leg is placed in a plaster cast from the toes to well above the knee. After four weeks a snugly fitting boot cast is applied and weight bearing is permitted gradually with the aid of crutches. Three months postoperatively a leather lacer brace is fitted from the toes to the knee, holding the ankle in the desired position and is worn continuously until consolidation is complete.

Hatt employs a central bone graft for fusion of the ankle. In his own cases, this graft has not caused premature arrest of growth, even though the graft is inserted across the center of an actively growing epiphysis. Further discussion of this procedure will be found below

Technic (Hatt).—A linear incision is made over the tibial crest from the middle third of the tibia to the neck of the astragalus. The bone is exposed subperiosteally, the ankle joint is opened, and the capsule is freed and retracted. The articular surfaces of the ankle joint are next destroyed the osteocartilaginous chips being left in situ this is accomplished by means of a rotary boring motion with a medium-sized curette A graft measuring one half by three inches is now removed from the lower third of the tibia, the distal saw cut being at least one-half inch above the distal tibial epiphysis. With a bayonet-shaped chisel, a tunnel is then made through the center of the distal end of the tibia and into the body of the astragalus while the foot and ankle are held in the desired position The chisel is removed and with a special bayonet shaped bone set the tibial graft is driven into the tunnel

After Treatment.—See p 995

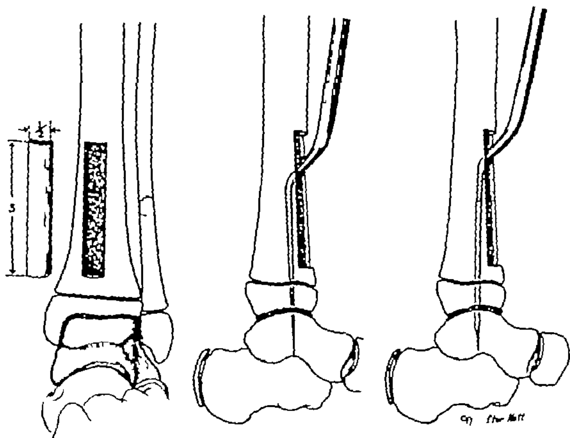


Fig. 6?8.—Central bone graft for fusion of ankle (Hatt) *A* Intraarticular arthrodesis accomplished by destruction of articular surfaces with boring motion of a curette chips left in place. Graft removed from lower third of tibia. *B* Tunnel created through center of distal end of tibia and into body of astragalus with bayonet-shaped chisel. *C* Tibial graft tapped in place with special bone set. (From Hatt, R. N : J Bone & Joint Surg. 22: 393, 1940.)

Posterior Arthrodesis of the Ankle Joint

Posterior fusion of the ankle joint (p 936) for nontuberculous affections is employed only in the event that both the subastragalar and the ankle joints are involved. In nontuberculous affections the capsule is incised transversely and the posterior extremity of the astragalus and articular surfaces of the posterior

aspect of the ankle joint are removed The surfaces of the subastragalar joint may be denuded likewise Bone flaps are then turned down from the tibia and up from the os calcis, but are impacted so as to come in contact not only with each other but with the posterior surface of the astragalus

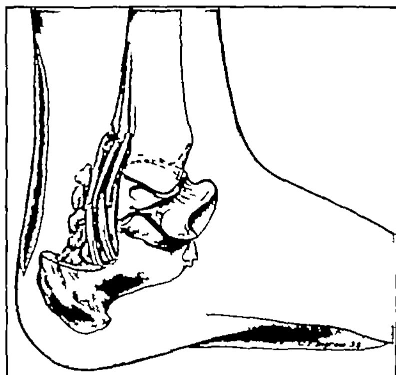


Fig. 6 6.—Posterior intra-articular arthrodesis of ankle and subastragalar joints.

KNEE

In actively growing extremities with intact epiphyseal plates internal fixation is usually contraindicated because of the possibility of damaging the plates and thus causing growth disturbances. Hatt, and others however have employed a central bone graft extending across the epiphyseal plates in fusions of the ankle and knee, without evidence of arrest of growth in these epiphyses These observations have been verified by Aries in experiments which showed that the longitudinal growth of bone does not take place in the form of lines parallel to the epiphyseal new bone having for its base the peripheral portion of the disc and possessing a wider perimeter than the old Hatt has reported an adequate follow up study on twenty three cases of arthrodesis of the ankle and twenty-one cases of arthrodesis of the knee by use of central bone graft, wherein the average increase in shortening following operation was not appreciable

Except in tuberculosis, Bosworth augments the ordinary methods of osseous fusions of the knee by the insertion of a Smith Petersen nail obliquely across the joint from the adductor tubercle of the femur into the tibial condyle Certainly in adults, some form of metallic internal fixation (Fig 677) or a graft is a desirable supplement to arthrodesing procedures. Other technics are described on p 937

Technic (Gray) —A four inch incision is made over the middle of the tibia and a bone graft, three inches long and one-fourth inch thick including the periosteum is removed from the tibial crest. This wound is then closed. The knee joint is exposed through a semicircular incision (p 143)

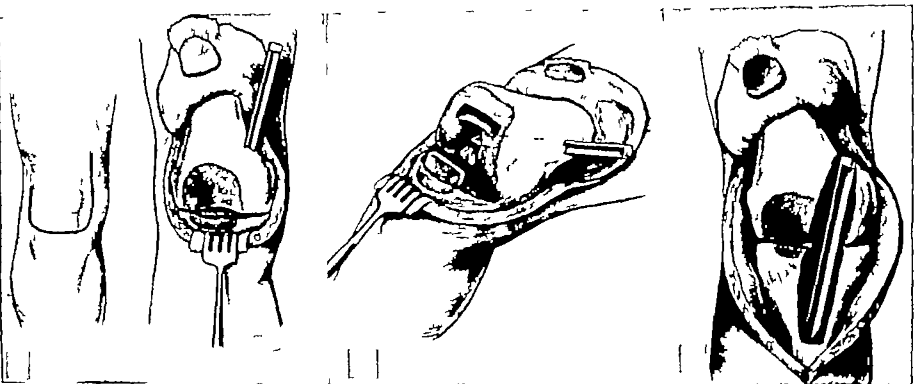


Fig. 677.—Bosworth technic of arthrodesis of knee. Medial limb of horseshoe-shaped incision extends proximally f r exposure of medial femoral condyle. After intra-articular arthrodesing procedures, denuded flat surfaces of femur and tibia are apposed and fixed in position by Smith Petersen nail. A screw may be used to fix patella to the tibia. (From Bosworth, D. M.: J Bone & J Int Surg. 28: 580 1946.)

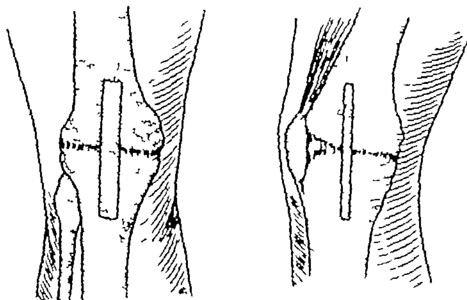


Fig. 678.—Intra-articular fusion of knee with large central autogenous bone peg (Key)

5

after Hatt

Fig. 679.—Arthrodesis of knee by central bone graft (Hatt) Shaded area represents sections of articular surfaces to be removed tibial graft removed with motor saw Tunnel created across joint line with bayonet chisel. Central graft tapped in place with bone set. (From Hatt, R. N J Bone & Joint Surg. 22: 393 1940)

which divides the ligamentum patellae. All cartilage is excised from the articular surfaces of the patella and condyles of the femur and tibia, and the semilunar cartilages are likewise removed. A small hole is drilled through the center of the epiphyses into the diaphyses of the tibia and femur the spicule graft is inserted into the femur and the tibia brought into proper apposition to the femur to allow the protruding portion of the graft to extend into the hole drilled in the tibia.

After Treatment —(See p 939)

Technic (Hatt) —The joint is exposed through a linear anterior approach from above the patella to the junction of the upper and middle thirds of the tibia. To prevent the upward displacement which often occurs when the muscle attachment remains the patella is dissected from the quadriceps femoris. The articular surfaces of the joint are removed with a saw or an osteotome and properly fitted The upper third of the tibial crest is next exposed, a transverse cut is made just below the level of the tibial tubercle and, with a motor saw a graft one-half inch by five inches is removed. A bayonet shaped osteotome is then driven upward from the graft bed across the joint line well into the femur The alignment is now checked and necessary adjustments in position are made. The instrument is then retracted leaving a tunnel through which the graft is driven by a bayonet-shaped bone set Care should be taken in handling the graft, especially if thin from atrophy to prevent fracture Finally the patella is denuded and placed across the joint.

After Treatment.—(See p 939)

Rotation Arthrodesis of the Knee

Roeren described this procedure in 1929 With a special instrument, consisting of two half-circle chisels held together by a sleeve with a bar in the center which fits between the articular surfaces, a circular section of bone is removed from the joint one-half being taken from the femur and one-half from the tibia These fragments are then rotated by the bar through 90 degrees thus forming two grafts of cavernous bone across the joint.

According to Milgram, the principal objections to the above procedure are (1) the difficulty in driving the chisel to the desired depth without injuring the important popliteal structures, and (2) since the cruciate ligaments are not removed, the tendency of the attached soft tissue to rotate the grafts toward the original position

Milgram has overcome these disadvantages by devising a special circular saw and chisel, which he describes as follows ' The cutting tool is a rotating cylindrical cup of thin crucible steel 1¾ inches in diameter The handle of this instrument contains a well into which fits accurately a cylindrical post one-fourth inch in diameter This post bears a thin, malleable transverse plate which can be curved at operation to slip between articular surfaces and rest against the posterior crucial ligament. Of major import is the fact that the post is of such length compared to the well that it projects five-eighths inch beyond the teeth of the circular saw After withdrawal of the cup saw the grafts are removed by means of a chisel having the same curve as the cup To prevent the grafts from rotating to their former positions, all soft tissues are detached.

Technic (Milgram) —Through a U-shaped incision, the patella and patellar tendon are turned upward and the upper one inch of the tibia is exposed. The anterior cruciate ligament is incised and the post so insertd into the joint

as to rest against the posterior cruciate ligament The cutting cup is inserted over the post and rotated backward and forward to the maximum depth allowed by the post After withdrawal of the post and cutting tool the semicircular sections of bone are divested of all attachments with curved scissors and the curved chisel and are rotated 90 degrees thus the former joint space of the two semicircular sections becomes vertical instead of horizontal The remaining articular cartilage is removed from the femur and tibia. Usually, the patella is too high above the graft area to be of osteogenic value.

After Treatment.—(See p 939)

This procedure is not suitable for the treatment of tuberculosis, wherein destruction of the articular ends of the bone has taken place, as the grafts may contain large tuberculous foci. Further, the operation is inadvisable for any affection, as old osteomyelitis adjacent to the joint, wherein large grafts are contraindicated Free grafts of such large dimensions may fail to unite to either the femur or tibia or both and, if absorbed or sequestrated the outcome will be disastrous. The operation should probably not be undertaken in children since the epiphyses might be damaged if the cutting cup is too large

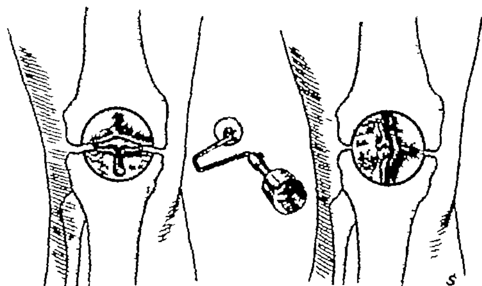


Fig. 430.—Rotation arthrodesis of knee. Insert shows special instrument devised by Milgram for cutting half-circle grafts. (Redrawn from Milgram, J E. Surg. Gynec., Obst. 53: 318, 1931)

HIP

Recognizing the need of a more effective fixation of the hip joint during the period of bony consolidation following arthrodesis than is afforded by the usual plaster cast alone Watson-Jones, in 1934 advocated the use of a Smith Petersen triflanged nail He inserted the nail into the anterior surface of the neck of the femur and through the femoral head into the acetabulum It was found, however that because of the thin floor of the acetabulum, the fixation thus afforded was inadequate In an effort to promote fusion by fixation alone Burns, in 1935 employed an extra large Smith Petersen type of nail, inserting it through the trochanter neck, and head of the femur, into the thickened portion of the ilium above the acetabulum This procedure was carried out under roentgenographic guidance and through a small lateral incision below the greater trochanter In 1938 Watson-Jones reported a series of cases wherein operative

fusion had been employed, followed after ten to fourteen days by the insertion of a long, heavy Smith Petersen nail as well as a smaller number of cases wherein an attempt was made to induce fusion by nailing alone in patients whose condition would not permit the more formidable open operation in addition He has now abandoned the use of the nail alone however, since fixation is not maintained unless the hip is almost completely stiff before operation

Haggart advocates the two-stage method of Watson-Jones in elderly individuals with degenerative arthritis of the hip when arthrodesis is otherwise contraindicated. He applies a short, single hip spica cast before allowing the patient out of bed

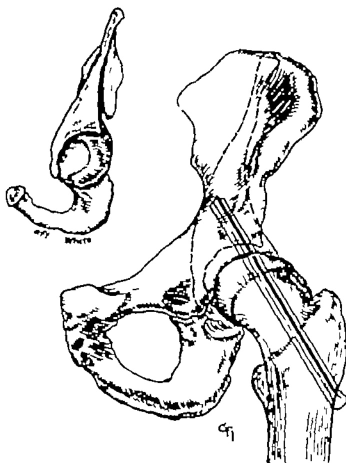


Fig 681.—Method of internal fixation of arthrodesis by a long Smith Petersen nail placed in thickest portion of ilium. (Cross section of ilium from White J W Lectures on Peace & War Orth. Surg Ann Arbo 1943 J W Edwards & Co.)

Blount and Moore use multiple nails of the Moore type, spreading them fan wise up into the acetabulum and ilium above and posterior to the acetabulum White has employed a Smith Petersen nail in the tuberculous hip wherein destruction has not extended so far as to prevent firm fixation of the nail in normal bone on each side of the joint. This procedure is designed to insure rest of the joint while providing fixation. In the presence of an associated deformity of sufficient degree, he has combined the use of the nail with a subtrochanteric osteotomy for correction of the deformity

Technic—First Stage.—Through the routine iliofemoral approach (p 146) a *simple intra-articular arthrodesis of the hip is performed* If desired small chip grafts from the adjacent ilium may be utilized to fill the defect between the head of the femur and the acetabulum which is produced by removal of the articular cartilage.

Second Stage—The patient is immobilized on the fracture table with the extremity in the position of choice for arthrodesis The hip is not deliberately flexed as the patient lies on the table the lordosis will be sufficient to give 160 to 140 degrees of flexion which is ample A two inch incision is made over the upper shaft of the femur the center of the incision being just below the lower margin of the greater trochanter A strong guide-wire is inserted along the axis of the neck of the femur and roentgenograms are made in both planes



Fig. 682.—Watson Jones fusion of hip joint.

If the wire is not lying precisely in the middle of the neck, as shown in the lateral view and in such an axis as to emerge in the roof of the acetabulum and point to the lower part of the sacroiliac joint in the anterior posterior view other wires are drilled in relation to the first until exactly this position is obtained A modified Smith Petersen nail constructed of 3 mm. steel, is selected. The nail is larger than that used for fractures of the neck of the femur being 15 mm. wide and 4¾ to 5½ inches in length. The proper length

is calculated by gradations one inch apart on the pin. The nail is then driven in and a cross pin is inserted through its head to prevent displacement.

After Treatment.—If there is the slightest *suspicion of splitting* of the femur a short spica cast is applied for the first few weeks, *otherwise, no cast* is used. The patient is allowed to be up within ten days or two weeks after operation.

Several authors have reported that this procedure may be followed by subtrochanteric fracture after the patient begins to walk These patients, therefore, should be warned against stumbling or falling during the early weeks of walking

For elderly patients with nontuberculous degenerative disease of the hip, Harris has modified the above technic by using two grafts in addition to the Smith Petersen triflanged nail, *without opening the hip joint itself.*

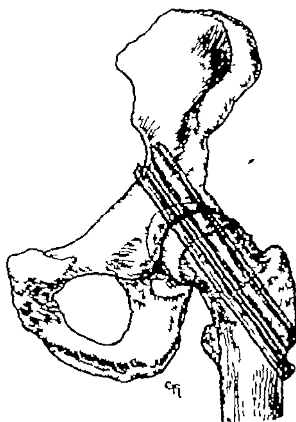


Fig. 6[illegible].—Arthrodesis of hip with triflange nail and tibial grafts. (From Harris R. I.: S. Clin. North America 2[illegible]: 141[illegible], 194[illegible].)

Technic (Harris).—The patient is placed upon the fracture table as described above, with provision for two-plane roentgenographic control. The hip and entire leg on the affected side are draped out into the sterile field. A sterile tourniquet is placed about the midthigh to control the blood loss associated with removal of the tibial grafts

A four inch lateral incision is made with its center over the trochanter and subtrochanteric region, and the bone is exposed subperiosteally A guide pin is passed from slightly below the center of the neck through the femoral head and the acetabulum and barely into the pelvis this is the *position* which the nail must finally occupy The pin may be inserted by any of the several methods in common use for the insertion of a Smith-Petersen nail for fracture of the neck of the femur (p 439)

If anteroposterior and lateral roentgenograms reveal the guide wire in a satisfactory position two others are inserted parallel to and above it, one in the anterosuperior portion of the neck and one in the posterosuperior portion. These must also just enter the pelvis, and their position must be checked by roentgenograms. While the films are being developed, the tibia is exposed.

A triflanged nail of appropriate length is driven along the lower guide pin to the proper depth, penetrating through the inner cortex of the pelvis. To prevent the nail from shattering the dense cortex in being driven through the bone, the cortex about the guide pin may be perforated with a cannulated reamer.

The position of the nail is checked by roentgenograms, and while the films are being developed two grafts are removed from the tibia. One graft, which is cut from the center of the bone, should be exactly one half inch wide and of sufficient length when cut in two to reach the full length of the tunnel to be prepared. The second graft, which is cut from the center of the tibial crest should be half the length of the first.

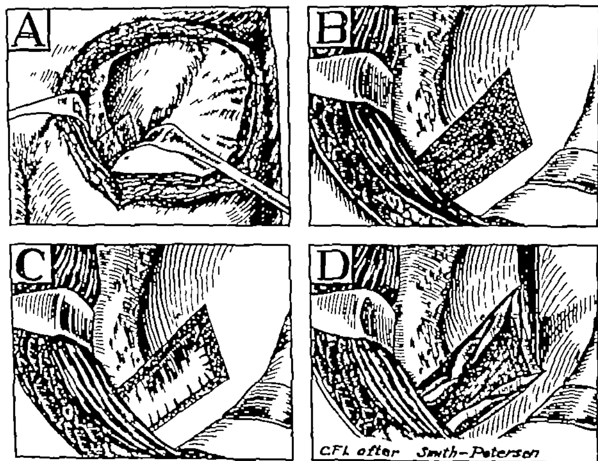


Fig. 684.—Smith-Petersen intra-articular arthrodesis of sacroiliac joint. *A*, Outline of section of bone removed from ilium, sacroiliac joint, and sacrum. *B*, After removal of bone plug. *C*, Cartilage resected from joint surface and block of bone replaced and countersunk. *D*, Edges of window osteotomized and fragments turned inward. (Redrawn from Smith-Petersen, M. N., and Rogers, Wm. A.: J. Bone & Joint Surg. 8: 118, 1926.)

A three-eighth inch cannulated reamer is then passed along one of the superior guide pins until it extends just into the pelvis. The long graft is cut in two pieces and the cortical surfaces are placed together; one end of this doubled graft is then pointed and the pair are driven through the tunnel prepared for their reception. Being slightly larger than the tunnel they fit snugly and provide additional fixation of the hip as well as close contact with the femur and acetabulum. A second tunnel three-eighths inch wide is drilled along the

remaining guide pin, and the second graft, from the crest of the tibia, is driven into this tunnel. The positions and in particular the depths of the grafts are checked by roentgenograms.

A heavy Kirschner wire is passed through the lower end of the femur and a plaster spica is applied, the ends of the wire being incorporated in the cast.

After Treatment—Two weeks after operation, the posterior half of the cast from the knee down is removed and, with the patient lying on his face, knee flexion exercises are instituted These are continued vigorously until the plaster immobilization is removed The transfixing Kirschner wire prevents free movement of the iliotibial band, and thus interferes to some extent with vigorous and full knee flexion, nevertheless, the wire should be retained for a month, since there is no other means of preventing rotational strains upon the hip when the leg and foot are out of the cast and the knee is flexed.

The cast is removed at the end of four months. The condition of the fusion is then checked by roentgenograms and, if found satisfactory the patient is allowed to be up If desired, the plaster may be removed at the end of three months, the wound reopened the triflanged nail removed, and a fibular graft from the same leg inserted into the space occupied by the nail. Following this procedure, no plaster immobilization is necessary

Technic (Dickson and Willien)—(See p 856)

SACROILIAC JOINT

Intra-Articular Arthrodesis

As previously stated, sacroiliac fusion is practically never indicated for tuberculosis. We can think of but one instance of a nontuberculous lesion wherein this procedure might be indicated namely old traumatic separation of the sacroiliac joint with persistent pain over a period of 18 months or two years. Ordinarily, in this length of time a patient will develop a spontaneous fusion of the sacroiliac joint and surgery consequently is unnecessary

Technic (Smith Petersen)—An incision is made along the posterior two-thirds of the iliac crest, curving around the posterior superior spine and then continuing parallel with the fibers of the gluteal muscles a distance of two or three inches. The soft tissues are reflected subperiosteally, exposing the lateral surface of the ilium. A rectangular window is then removed from the ilium directly over the sacroiliac joint. The sacral surface of the joint is divested of cartilage down to cancellous bone After resection of the cartilage from the joint surface of the block of bone, the block is replaced and counter sunk so that its cancellous surface comes in contact with the cancellous bone of the sacrum The countersunk block is further secured and osteogenesis promoted by an osteotomy of the edges of the window and turning of the fragments inward (Fig 684)

After Treatment.—(See p 965)

SHOULDER

The intra-articular and extra articular arthrodeses of the shoulder joint described by Gill and Putti were primarily devised for nontuberculous affections. Since they are adaptable to tuberculosis, however the technics are given in that section (p 979)

Intra-articular arthrodesis alone as described by Steindler is inadequate in the majority of cases, although the procedure is valuable if supplemented

by bone flaps or grafts to provide a bony bridge between the humerus and acromion

Technic (Steindler)—The shoulder joint is approached through an incision which begins at the spine of the scapula, then curves downward and forward below the head of the humerus, and ends with an upward curve over the coracoid process. The flap thus outlined is turned upward to expose the edge of the acromion process. The middle portion of the deltoid muscle is defined and incised longitudinally from its insertion upward to the acromion The extremity of the acromion is next divided and with the muscle flap is reflected downward The capsule of the joint is incised longitudinally to the glenoid fossa at this point transverse incisions are added opening the entire anterior half of the sac. All cartilage is removed from the glenoid cavity and from the head of the humerus. With the arm in abduction the two freshened articular surfaces are approximated and maintained in position by catgut sutures passed through drill holes in the head of the humerus and in the acromion process. The muscle flap is sutured posteriorly to the spine of the scapula serving as a hammock against which the head of the humerus rests, and counteracting immediate backward dislocation

After Treatment.—(See p 980)

The following technic, wherein a tibial graft is utilized to traverse the shoulder joint, has been advocated by Putti for fusion of the shoulder in tuberculosis. Although the author has had no experience with this method in the shoulder similar technics for tuberculosis of the knee have not been satisfactory as the grafts fractured or were absorbed When augmented by intra articular arthrodesis, the procedure should be excellent for non tuberculous lesions of the shoulder Leveuf and Bertrand and Brett employ a somewhat similar procedure

Technic (Putti)—An incision two inches in length is made over the lateral aspect of the shoulder joint the deltoid muscle is incised longitudinally and the head of the humerus exposed. After elevation of the fascia and periosteum the shoulder is maintained in the most serviceable position until the operation is complete. A tunnel of sufficient diameter to contain the tibial transplant is then made through the head of the humerus, across the shoulder joint, and into the glenoid A straight graft, approximately one-fourth inch in width and of a length commensurate with the length of the tunnel in the shoulder is removed from the tibia and driven into the tunnel

After Treatment.—(See p 980)

ELBOW AND WRIST

The technics of fusion of the elbow and wrist for nontuberculous lesions are identical to those described for tuberculous joints (pp 983 987)

References

Abbott, L. C., and Fischer F J Arthrodesis of the Hip With Special Reference to the Method of Securing Ankylosis in Massive Destruction of Joint, Surg Gynec. Obst. 52 563 1931.

Abbott L. C., and Gill G G The Use of Cancellous Bone Grafts in Orthopedic Surgery Brunn, Med. Surg Tributes 1942, University of California Press.

Abbott L. C., Saunders, J B deC. M., and Bost F C. Arthrodesis of the Wrist With the Use of Grafts of Cancellous Bone J Bone & Joint Surg 24 883 1942

Albee Fred H. A Report of Bone Transplantation and Osteoplasty in the Treatment of Pott s Disease of Spine New York M. J 95 469, 1912.

— Arthritis Deformans of Hip; Report of a New Operation J A. M. A. 50 1653 1908.

—: Bone-Graft Surgery Philadelphia, 1915 W B. Saunders Co.
— Extraarticular Arthrodesis of the Hip for Tuberculosis, With Report of 31 Cases, Ann. Surg 89 404 1929
—: Extraarticular Arthrodesis of the Hip by Bone Graft, for Tuberculosis of the Hip, Am. J Surg 8 764, 1930
— Orthopedic and Reconstruction Surgery Philadelphia, 1919 W B. Saunders Co., p. 418.
— Pott's Disease The Operation of Bone Grafting for Its Cure, as Devised by Dr F H Albee of New York, Surg Clin. of John B Murphy 2: 465, 1913.
— The Bone-Graft Operation for Tuberculosis of the Spine 20 Years' Experience, J A. M A. 94 1467 1930
— Transplantation of a Portion of the Tibia into the Spine for Pott's Disease A Preliminary Report J A. M. A 57 885, 1911
Allison, N: Fusion of the Spinal Column, Surg Gynec. Obst. 46 826, 1928.
Aries, L. J *Experimental Analysis of Growth Pattern and Rates of Appositional and* Longitudinal Growth in Rat Femur Surg Gynec. Obst. 72 679 1941.
Badgley Carl Personal communication 1947
Baker Lenox, D Personal communication, 1946.
Baker, Lenox D., and Hoyt, Walter A., Jr The Use of Interfacet Vitallium Screws in the Hibbs Fusion, South M. J 41 419, 1948.
Bankart, A. S B The Treatment of Tuberculous Disease of the Hip Joint, Brit. J Surg 20 551, 1933
Bick, Edgar M.: History and Source Book of Orthopaedic Surgery New York, 1933, The Hospital for Joint Diseases, p. 159
Blount, Walter: Personal communication, 1946 and 1947
Bosworth, D M. Clothespin Graft of the Spine for Spondylolisthesis and Laminal Defects, Am. J Surg 67 61, 1945.
Bosworth, D M.: Femoro-Ischial Transplantation, J Bone & Joint Surg 24 38, 1942.
Bosworth D M. Knee Fusion by the Use of a Three-Flanged Nail, J Bone & Joint Surg 28 550, 1946.
Bosworth, D M. Tuberculosis of the Osseous System Operative Methods, Quart. Bull., Sea View Hosp. 5 441, 1940
Brett A. L.: A New Method of Arthrodesis of the Shoulder Joint Incorporating the Control of the Scapula, J Bone & Joint Surg 15 969, 1933.
Breck L. W., and Basom, W C. The Flexion Treatment for Low Back Pain. Indications Outline of Conservative Management and a New Spine-Fusion Procedure, J Bone & Joint Surg 25 58 1943
Bristow W R.: Arthrodesis, Brit. J Surg 15 401, 1928.
Brittain, H. A.: Architectural Principles in Arthrodesis Baltimore 1942, Williams & Wilkins Co
Brittain, H. A. Ischiofemoral Arthrodesis Brit. J Surg 29 93, 1941.
Burns, B H.: Fixation of the Osteo-Arthritic Hip by Nailing Lancet 1 978 1939
Burns, B. E. The Use of Staples in Bone Surgery Privately Mimeographed, 1946.
Campbell Willis C. Animal Experiments in an Operative Procedure for Fusion of the Sacro-Iliac Joint, South. M. J 24 186 1931.
—: An Operation for Extra Articular Fusion of the Sacro-Iliac Joint, Surg Gynec. Obst. 45 218, 1927
— An Operation for the Induction of Osseous Fusion in the Ankle Joint, Am. J Surg 6 588 1929
—: Fusion of Tuberculous Joints, Surg Clin. of North America 10 833, 1930
— Injuries and Surgical Diseases of Joints. Dean Lewis Practice of Surgery Hagerstown, 1928 W F Prior Co., Inc., Vol. II, Chap. V
— Operative Measures in the Treatment of Affections of the Lumbosacral and Sacro-Iliac Articulation, Surg Gynec. Obst. 51 381 1930.
— Operative Measures in the Treatment of Low Back Pain, Tr South. S. A. 42. 207 1929
Chandler, F A.: Hip-Fusion Operation J Bone & Joint Surg 15 947, 1933.
Cleveland, Mather Operative Fusion of the Unstable or Flail Knee Due to Anterior Poliomyelitis. A Study of the Late Results, J Bone & Joint Surg 14 525 1932.
Cleveland Mather and Smith, A. DeF Fusion of the Knee Joint in Cases of Charcot's Disease. Report of Four Cases, J Bone & Joint Surg 13 849 1931.
Colonna, P C. A Method for Fusion of the Wrist, South. M. J 37: 195, 1944.
Colonna, P C Personal communication, 1947
Delangenière H., and Lewin, Philip A General Method of Repairing Loss of Bony Substance and of Reconstructing Bones by Osteoperiosteal Grafts Taken from the Tibia, Surg Gynec. Obst. 30 441 1920
Dickson, J A. and Willien L. J Arthrodesis of the Hip Joint in Degenerative Arthritis. A Modified One-Stage Procedure With Internal Fixation, J Bone & Joint Surg 29 687 194
Eycleshymer, A. C. and Schoemaker D M. A Cross-Section Anatomy New York, 1911 D Appleton & Co
Freiberg, J A Experiences With the Brittain Ischiofemoral Arthrodesis, J Bone & Joint Surg 28 501, 1946.

Gaenslen, F J : Sacro-Iliac Arthrodesis Indications, Author's Technic and End Results, J A. M. A. 89 2031 1927
Galloway, H. P H. The Patellar Bone-Graft in Excision of the Knee Am J Orthop. Surg. 15 704 1917
Gellman M : Arthrodesis of the Elbow A Preliminary Report of a New Operation J Bone & Joint Surg 29 850, 1947
Ghormley R. K.: Use of the Anterior Superior Spine and Crest of Ilium in Surgery of the Hip Joint, J Bone & Joint Surg 13 784 1931.
Ghormley R. K., and Wesson H R.: Surgical Treatment (Fusion of Lumbosacral or Sacro-Iliac Joints) of Low Back Pain and Sciatica, South. M. J 30: 806 1937
Gibson, A.: A Modified Technique for Spinal Fusion, Surg Gynec. Obst. 53 305 1931
Gill A. Bruce Orth. Corresp. Club Letter, March 20 1947
Gill, A. Bruce: A New Operation for Arthrodesis of the Shoulder J Bone & Joint Surg 13 287 1931
Girard, P M.: Hip Joint Fusion and the Shelf Operation, J Bone & Joint Surg 17 443 1935.
Girdlestone, G R.: Arthrodesis and Other Operations for Tuberculosis of the Hip. The Robert Jones Birthday Volume, London, 1928, Oxford University Press, p. 347
— The Pathology and Treatment of Tuberculosis of the Knee-Joint, Brit. J Surg 19 488, 1932.
Gray H. T The Stabilization of the Flail Leg, Brit. J Surg 15 390 1928
Hadra, B. E.: Wiring the Spinous Processes in Pott's Disease Tr Am. Orthop A. 4 206 1891.
— Wiring of the Vertebrae as a Means of Immobilization in Fracture and Pott's Disease, Times & Reg 22 423, 1891
Haggart G E.: Degenerative Arthritis of the Hip Joint Treated by One or Two Stage Arthrodesis With Metal Fixation (Watson-Jones) J A. M. A. 128 502, 1945
Hallock, Halford: Fusion of the Elbow Joint for Tuberculosis. A New Technique and a Report of Three Cases, J Bone & Joint Surg 14 145, 1932.
Harris, R. I. Arthrodesis of the Hip Joint; New and Simple Operation S. Clin. North America 23 1412 1943
Hass, J : Extra Articular Ankylosis of the Hip Zentralbl. f Chir 49 1466 1922.
Hatt, R. N : The Central Bone Graft in Joint Arthrodesis, J Bone & Joint Surg 22 393 1940.
Hatt, R. N : The Central Bone Graft in Joint Arthrodesis, Arch. Surg 46 664 1943.
Henderson, Melvin S. Combined Intra Articular and Extra Articular Arthrodesis for Tuberculosis of the Hip Joint, J Bone & Joint Surg. 15 51 1933
— Operative Fusion for Tuberculosis of the Spine J A M. A. 92 45 1929
— Treatment of Tuberculosis of the Hip Londres, 1933, Deuxieme Congres de la Societe Internationale de Chirurgi Orthopedique, p. 317
Henderson, Melvin S., and Fortin, Harry J Tuberculosis of the Knee Joint in the Adult, J Bone & Joint Surg. 9 700 1927
Henry Myron O : Chip Grafts in Orthopaedic Surgery J Bone & Joint Surg 19 1057 1937
Henry M O., and Geist, E. S.: Spinal Fusion by Simplified Technique, J Bone & Joint Surg 15 622, 1933.
Hibbs, Russell A. A Further Consideration of an Operation for Pott's Disease of the Spine Ann. Surg 55 682, 1912.
— An Operation for Pott's Disease of the Spine J A M. A. 59 433 1912.
—: An Operation for Progressive Spinal Deformities, New York M J 93 1013, 1911
—: An Operation for Stiffening the Knee-Joint Ann. Surg 53 404 1911.
— A Preliminary Report of Twenty Cases of Hip Joint Tuberculosis Treated by an Operation Devised to Eliminate Motion by Fusing the Joint J Bone & Joint Surg 8 522, 1926.
Hibbs, R A., and von Lackum, H. L. End Results in Treatment of Knee Joint Tuberculosis, J A. M. A. 85 1289 1925
Hibbs, Russell A., and Risser Joseph C Treatment of Vertebral Tuberculosis by the Spine Fusion Operation. A Report of 286 Cases, J Bone & Joint Surg 10 805 1928.
Howorth, M B Evolution of Spinal Fusion, Ann. Surg 117 278, 1943.
Howorth M. B. Personal communication 1947
Key J A Arthrodesis of the Shoulder Am. Acad Orthop. Surgeons Reconstruction Surgery of the Extremities Ann Arbor Michigan, 1944, J W Edwards
Key J Albert Arthrodesis of the Knee with a Large Central Autogenous Bone Peg South. M. J 30 574 1937
— Positive Pressure in Arthrodesis for Tuberculosis of the Knee Joint, South. M. J 25 909 1932.
Kidner F C. End Results of Extra Articular Fixation of the Tuberculous Hip in Children, J A M. A. 91 1805 1928
King D Internal Fixation for Lumbosacral Fusion, Am. J Surg 66 357 1944.
King Don Personal communication, 1947

Kite J H. Non-Operative Versus Operative Treatment of Tuberculosis of the Spine in Children; Review of 50 Consecutive Cases Treated by Each Method, South. M. J 28 918, 193..

Knight, R. A., and Bluhm, M. M. Brittain Ischiofemoral Arthrodesis, J Bone & Joint Surg 27 578, 1945.

Lange, F: Support for the Spondylitic Spine by Means of Buried Steel Bars, Attached to the Vertebrae Am. J Orthop. Surg 8 344 1910

— The Operative Splinting of the Vertebral Column in Pott s Disease, Surg. Gynec. Obst. 44 668, 1927

Leveuf, J., and Bertrand, P A New Procedure for Arthrodesis of the Shoulder: Fixation Buttress by Tibial Graft, Internat. Abstr Surg 66 494 1938. (Abstracted from J de chir 50 593 1937)

Lewin, Philip: A Proposed Modified Fusion Operation on the Spine J Bone & Joint Surg. 6 162 1924

Liebolt, F L: Surgical Fusion of the Wrist Joint, Surg Gynec. Obst. 66 1008, 1938.

Logroscino R. Arthrodesis of the Shoulder According to Putti, Internat. Abstr Surg 68. 87, 1938 (Abstracted from Arch. ital. di chir 45 501 1937)

McCarroll, H. R., and Heath R. D: Tuberculosis of the Hip in Children. Certain Roentgenographic Manifestations, Secondary Changes in the Extremity, Some Suggestions for a Program of Therapy J Bone & Joint Surg 29 889 1947

McKeever, F M.: Tuberculosis of the Knee in Infancy and Childhood, J A. M. A. 113 1293, 1939

Milgram, J E.: Arthrodesis of the Knee, Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities Ann Arbor Michigan 1944 J W Edwards.

Milgram, J E. A Modification of the Rotation Arthrodesis of the Knee (Roeren) Surg Gynec. Obst. 53 355 1931

Moore, A. T: The Unstable Spine; Discogenetic Syndrome Treatment With Self Locking Prop Bone Graft, J Internat. Coll. Surgeons 8 64 1945; Correction 8 179 1945.

Pease, C. N: Fusion of the Hip in Children. The Chandler Method J Bone & Joint Surg. 29 874, 1947

Petter Charles K. Rib-Splinter Graft in Spinal Fusion for Vertebral Tuberculosis, J Bone & Joint Surg 19: 413 1937

Putti, V Arthrodesis for Tuberculosis of the Knee and of the Shoulder Chir d. org di movimento. 18 217 1933

Rocher H. L. Technique Simplifiée pour l Arthrodèse Extra Articulaire de la Hanche par Greffon Tibial dans la Coxalgie Type 37 (Simplified Technique for Extra Articular Arthrodesis of the Hip by Means of Tibial Graft) J Bone & Joint Surg 19 1160 1937 (Abstracted from J de méd. de Bordeaux 114 09 1937)

Roeren, L. Die Drehversteifung, Ztschr f orthop Chir 52 271 1929.

Rountree C. R. Personal communication, 1947

Ryerson, E. W Surgical Treatment of Low Back Disabilities, J Bone & Joint Surg 14 164, 1932.

Schumm, H. C. Extra Articular Immobilization of the Hip Joint, Surg Gynec. Obst. 48 112, 1929

Schwartz, R. P Arthrodesis of Subtalus and Midtarsal Joints of the Foot, Historical Review Preoperative Determinations, and Operative Procedure Surgery 20 619 1946.

Seddon H. J., and Strange F G St. C. Sacro-Iliac Tuberculosis, Brit. J Surg 28 193, 1940

Smith-Petersen, M. N and Rogers, Wm. A.: Arthrodesis for Tuberculosis of the Sacro-Iliac Joint Study of the End Results, J A. M. A. 86: 26, 1926.

— End Result Study of Arthrodesis of the Sacro-Iliac Joint for Arthritis—Traumatic and Non Traumatic, J Bone & Joint Surg 8 118 1926.

Sorrel, E. The Indications for and Results of Osteosynthesis in the Treatment of Pott's Disease Internat. Abstr Surg 50 357 1930 (Abstracted from J de chir 34 449 1929)

Speed, J S., and Boyd, H. B Operative Reconstruction of Malunited Fractures about the Ankle Joint, J Bone & Joint Surg 18 270 1936.

Speed, K. Hip Joint Fusion, Surgery 1 40, 1937

Steindler, Arthur Orthopedic Operations Indications Technic and End Results, Springfield, Ill., 1940 Charles C Thomas.

Steindler, Arthur: Arthrodesis of the Shoulder, Am. Acad Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor, Michigan, 1944, J W Edwards.

Steindler Arthur Reconstruction Surgery of the Upper Extremity New York, 1926, D. Appleton & Co.

Toumey J W Internal Fixation in Fusion of the Lumbosacral Joint, Lahey Clin. Bull. 3 183 1943

Trumble, H. C. A Method of Fixation of the Hip-Joint by Means of an Extra Articular Bone Graft, Australian & New Zealand J Surg 1: 413, 1932.

—: Fixation of the Hip-Joint by Means of an Extra Articular Bone Graft Late Results, Brit. J Surg 24 728 1937

Van Otterloo J de Mol. 'Spondylodesis ' J Bone & Joint Surg 20 320 1938
Wagoner, G: A Technique for Lessening Hemorrhage in Operations on the Spine J Bone & Joint Surg 19 469 1937
Watson-Jones, R.: Arthrodesis of the Osteoarthritic Hip, J A M A 110 278 1938
Watson-Jones, R: Fractures and Joint Injuries ed 3 Baltimore, 1946 Williams & Wilkins Co
Watson-Jones, R. Arthrodesis of the Osteoarthritic Hip J A. M A. 110 278 1938
— Extra Articular Arthrodesis of the Shoulder J Bone & Joint Surg 15 862 1933
White J W Smith Petersen Nail Fixation in Hip Disease South M J 36 333 1943.
White, J W: Smith Peterson Nail in Hip Disease Lectures on Peace and War Orthopaedic Surgery, Am. Acad. Surg, Ann Arbor, Michigan, 1943, J W Edwards.
Whitman, A.: Rib Grafting for Scoliosis, Am. J Surg 6 801 1929
Williams, P C. Lesions of the Lumbosacral Spine Chronic Traumatic (Postural) Destruction of the Lumbosacral Intervertebral Disc, J Bone & Joint Surg 19 690 1937
Wilson, John C.: Extra Articular Fusion of the Tuberculous Hip Joint, California & West. Med. 27 774, 1927
— Operative Fixation of Tuberculous Hips in Children. End Result Study of Thirty Three Patients from the Orthopaedic Department of the Children's Hospital, J Bone & Joint Surg 15 22, 1933.

CHAPTER XVI

ANKYLOSIS AND DEFORMITY

Ankylosis is the restriction of motion in joints as the result of a pathologic condition of the intra articular or extra articular structures. The etiologic factors may be enumerated as follows (1) intra articular affections, such as (a) acute infectious arthritis, (b) penetrating wounds from without, as gunshot wounds complicated by infection, (c) low-grade affections, as tuberculosis, syphilis, and atrophic and hypertrophic arthritis, and (d) comminuted fractures terminating in irregularities which block joint motion and (2) extra-articular affections, such as (a) contractures of the periarticular structures secondary to affections of joints, (b) primary pyogenic infections of the soft structures, (c) pyogenic infections of the soft structures secondary to osteomyelitis, (d) crushing and laceration of the soft tissues associated with compound or closed fractures, with or without infection and (3) contractures of overactive or unopposed muscle groups, as in acute poliomyelitis or spastic paralysis.

In intra articular ankylosis, motion is restricted by fibrous or osseous union of the joint surfaces, both of which may be produced by the same agent Although osseous fusion is often termed true ankylosis, from either a clinical or surgical aspect there is no material difference between a strong fibrous ankylosis with slight motion, and bony ankylosis.

In extra articular ankylosis, motion is restricted by scar tissue formation and contracture of the soft structures, as skin capsules, fasciae, ligaments, and muscles, following the inflammatory reaction.

When the ankylosis is primarily intra articular there is always some degree of extra-articular ankylosis. Extra articular ankylosis, however may take place independently in this event, the secondary changes in the joint are usually of no practical significance The surgeon should be familiar with the varying degrees of decalcification of the bones or osteoporosis which may be demonstrated in the roentgenogram in both types, in order to be on guard against producing fracture by the use of excessive force when the joint is mobilized

In either intra articular or extra-articular ankylosis, efficient treatment during the active stage of the disease will serve to place the joint in a position for functional use of the extremity even though motion is partially or completely lost. Without proper treatment deformity may be so severe that function is impossible.

Obviously the most favorable time for operation is after the active process has subsided Infectious lesions must have been quiescent for a period of at least four months. During the active stage of some of the low grade

affections, as atrophic arthritis, surgery may be employed to correct deformities or restore function such measures, however are not advisable if there is any likelihood of arresting the process within a reasonable period of time by less radical treatment.

In extra-articular ankylosis, an attempt should usually be made to correct the deformity by conservative methods before operation is undertaken By preliminary stretching of the contractures, plastic procedures become more simple and less extensive and serious damage to the nerves and blood vessels by sudden extension is avoided The degree of correction secured depends largely upon the tensile strength and resiliency of the contracted structures. In the presence of an advanced pathologic process of long standing full correction is seldom attained by conservative measures alone.

Brisement Forcé

The forcible induction of motion by breaking up adhesions is a procedure widely employed but seldom advisable Brisement forcé is indicated chiefly in traumatic lesions, before adhesions are well organized, and is more effective in the shoulder than in any other joint. If the roentgenogram demonstrates extensive osteoporosis, the utmost care must be taken to prevent crushing or compression of the articular surfaces. Slight fractures often occur, even with the exercise of extreme caution, and gross fractures are not uncommon. Under no circumstances should ' pump handle ' methods be used excessive force will induce a reaction so violent that early active and passive motion will be impossible, and the purpose of the procedure thereby defeated.

After treatment should consist of the application of hot wet packs for forty-eight hours, supplemented every two hours by passive motion. Active motion is encouraged as soon as possible. At the end of four weeks, if motion has materially increased and acute symptoms have subsided, a second forcible attempt may be made. This procedure is repeated until the range of motion is adequate Of course if motion is regained rapidly after the first use of force, no further attempt should be made

In the majority of cases, function can be restored more satisfactorily by gentle force and physical therapy than by this method. Brisement forcé should be reserved for resistant cases, and even in these the results are usually disappointing

Osteotomy-Osteoclasis of Long Bones

Moore describes a method for correcting deformities of the long bones wherein the bone is divided to approximately three-fourths of its circumference at the site of maximum deformity and is followed later by manual osteoclasis of the remainder of the bone Irwin employs a similar technic for subtrochanteric osteotomy The procedure is applicable to malunited fractures, joints ankylosed in a position of deformity genu valgus or varus deformities coxa vara cubitus varus, and other deformities.

In 1939 Ferguson Thompson, and King reported a two-stage procedure for areas where a one-stage osteotomy was likely to be followed by either nonunion or loss of position. In their technic a rectangular segment consisting of one-half of the width of the bone is removed from the concave side of the deformity This

is broken up into bits and packed back into the defect. The osteotomy is completed on the convex side of the deformity some three weeks later, a lateral wedge being removed at about the middle of the level of the previous defect. The second stage is not performed until adequate callus has formed if necessary additional grafts are placed in the defect before the second stage osteotomy

Technic (Moore) —After exposure of the point of maximum deformity with care to preserve the periosteum a wedge of bone is removed either through the site of maximum deformity, or just proximal or distal. The osteotomy should be performed through relatively normal bone The size of the cuneiform wedge is proportionate to the deformity usually being slightly larger than necessary to insure easy correction. The wedge should include three cortices the fourth cortex is drilled once or twice with a three-sixteenth-inch drill. The cuneiform wedge of bone is then broken up into small grafts and replaced in the defect. The periosteum is carefully resutured in order to form a limiting membrane and maintain the chips in their proper position.

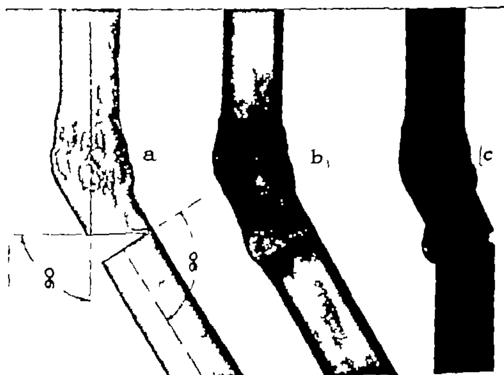


Fig. 685 —Osteotomy-osteoclasis of long bones (J R. Moore) *a*, Cuneiform wedge of bone removed distal to malunion through normal bone, leaving medial cortex intact. Note that proximal cut is at a right angle to longitudinal axis of proximal fragment distal cut is at a right angle to longitudinal axis of lower fragment. *b* Consolidation of grafts, with new callus partially eradicating defect. *c* Correction of deformity completed by manual osteoclasis. (From Moore, J R. J Bone & Joint Surg. 29: 119 1947)

After Treatment.—A plaster cast of appropriate size is applied. Approximately twenty-one days postoperatively in children, and twenty-eight days postoperatively in adults, a cylindrical section is removed from the cast at the operative site, and under anesthesia manual osteoclasis is performed. It is important that the axis of the wedge be determined so that force may be properly applied to produce a fracture with minimal effort, and with the least displacement of the fragments. The defect in the cast is filled in with plaster In children, immobilization is continued for six weeks, and in adults from eight to twelve weeks.

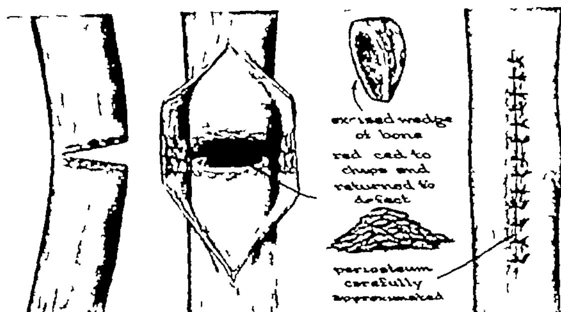


Fig. 686.—Same as Fig. 685. Detail of technic wedge of bone removed, reduced to chips, replaced in defect, and periosteum carefully closed. (From Moore, J R. J Bone & Joint Surg. 29: 119 1947)

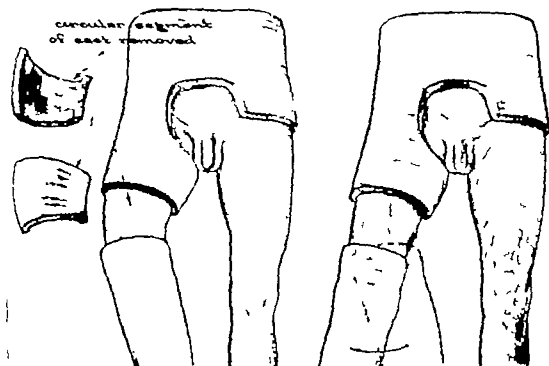


Fig. 687.—Same as Fig. 685 Three to four weeks after osteotomy cylindrical section of cast is removed. Correction completed by manual osteoclasis. Defect in plaster is filled in with reinforcements and circular plaster (From Moore, J R. J Bone & Joint Surg 29: 119 1947)

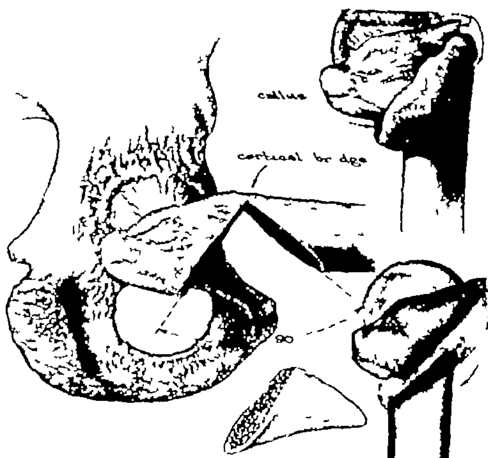


Fig. 688.—Osteotomy-osteoclasis for correction of flexion deformity with ankylosed hip. (From Moore, J. R. J. Bone & Joint Surg. 29: 119 1947.)

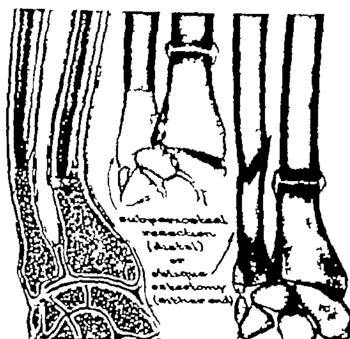


Fig. 689.—Osteotomy-osteoclasis of shaft of radius. (From Moore, J. R. J. Bone & Joint Surg. 29: 119 1947.)

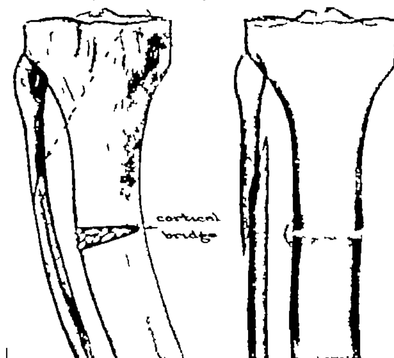


Fig. 690.—Osteotomy-osteoclasis for deformity of middle and upper third of tibia. (From Moore, J. R.: J. Bone & Joint Surg. 29: 119, 1947.)

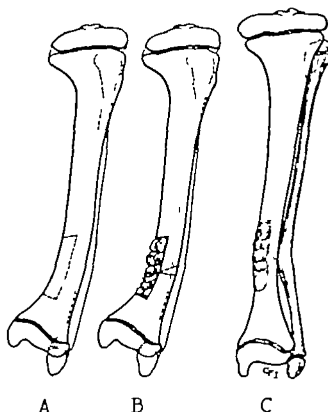


Fig. 691.—Two-stage osteotomy (Ferguson, Thompson, and King). *A*, Medial half of fibia removed and cut into chip grafts. *B*, Chips placed in defect. Dotted line indicates wedge to be cut at second stage to complete correction of varus deformity. Second stage is delayed until adequate callus has formed across first-stage defect. *C*, Procedure completed.

CORRECTION OF DEFORMITY IN INTRA ARTICULAR AND EXTRA ARTICULAR ANKYLOSIS

Formerly surgical procedures for the correction of deformities consisted principally of blind severance of structures by subcutaneous methods, such as subcutaneous tenotomy fasciotomy and osteotomy Since the development of more effective aseptic technics however, these have been replaced to a large extent by well planned open operations directed toward conservation of function and as nearly as possible restoration of anatomic relationships. A careful severance of a tendinous attachment and transference to a point which will *permit correction of a malposition without interference with the nerve or* blood supply is obviously much more satisfactory than blind tenotomy or fasciotomy which often leaves large dead spaces to be filled with blood clots and, subsequently fibrous tissue, and not infrequently impairs the muscle power of the member Scar tissue which forms following blind methods, or following unduly traumatic open operations, may contract, causing recurrence of the deformity and increasing the difficulty of later surgical procedures.

Osteotomy adjacent to the affected joint and the creation of a compensatory deformity of the bone in the opposite direction from the existing deformity of the joint are still of value in selected cases. More scientific measures, however are preferred when feasible.

FOOT

Deformities of the toes and foot which develop most often from poliomyelitis, such as clawtoes, and valgus, varus, calcaneus, and cavus, as well as those of static origin, such as hammertoe and planus, are described in the chapters on these subjects. Congenital equinovarus is discussed in Chapter XXV

ANKLE

Extra-Articular Ankylosis of the Ankle in Equinus

In periarticular contractures of the ankle, the position is virtually always equinus, from shortening of the tendo achillis alone, or shortening of both tendon and posterior capsule. Some degree of varus or valgus deformity may also be present. The operations for associated varus or valgus are described in Chapters XXII XXIV and XXV

Lengthening of the Tendo Achillis

In 1943 White presented a method of lengthening of the tendo achillis, which he has used for many years. The operation is based upon his observation that the tendo achillis rotates approximately 90 degrees on a vertical axis between its origin and insertion the rotation being from medial to lateral as seen from its posterior surface.

Technic (White) —Through a posteromedial incision four inches in length the calcaneal tendon is exposed and its anterior two-thirds is incised at a suitable point near its insertion While a moderate dorsiflexion force is applied to the foot, the medial two-thirds of the tendon is sectioned two or three inches proximal to the original incision The tendon thus lengthens as the foot is dorsiflexed. Suture of the tendon is unnecessary

After Treatment.—(See page 1022.)

Cummins and his associates, undertook extensive anatomic studies of 100 specimens of calcaneal tendons. Although some degree of rotation was observed in all the specimens the amount varied In order to record the degree of rotation conveniently, the tendons were arranged in three groups Group one included the tendons having least rotation which comprised 52 per cent of the total In this group, the posterior surface of the tendon was composed of one-third of the soleus and two thirds of the gastrocnemius Group two representing 35 per cent of the cases, included those tendons whose posterior surfaces were formed equally by the soleus and the gastrocnemius Group three, wherein rotation was extreme represented 13 per cent of the specimens studied in these the posterior surface of the tendon consisted of two thirds of the soleus and one-third of the gastrocnemius The rotation began approximately 12 to 15 cm. from the insertion of the tendon or about the level at which the soleus begins to contribute fibers to the tendon The plantaris

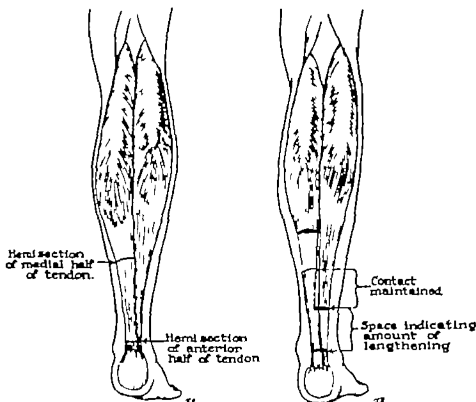


Fig. 692.—White's technic of lengthening Achilles tendon by hemisection of proximal and medial half and distal anterior half (From White, J W Arch. Surg. 46: 784 1943 Courtesy of Dr C. H. Heyman.)

tendon when present lies directly medial to the calcaneal tendon at its insertion. As a result of these observations Hauser devised the following procedure

Technic (Hauser).—The proximal tendon is incised first at a level three to five inches above the insertion, depending upon the amount of correction desired. A tenotome is inserted transversely into the calcaneal tendon so that two-thirds of the structure lies posterior to the blade. On insertion the blade should be parallel with the tendon it is then turned to face posteriorly and the tendon is cut through toward the skin. The distal incision should be placed one half inch proximal to the insertion of the tendon A curved tenotome is introduced deep to the medial two-thirds of the tendon and drawn posteriorly and medially to divide the tendon at this point The tendon glides apart as a dorsi flexion force is applied.

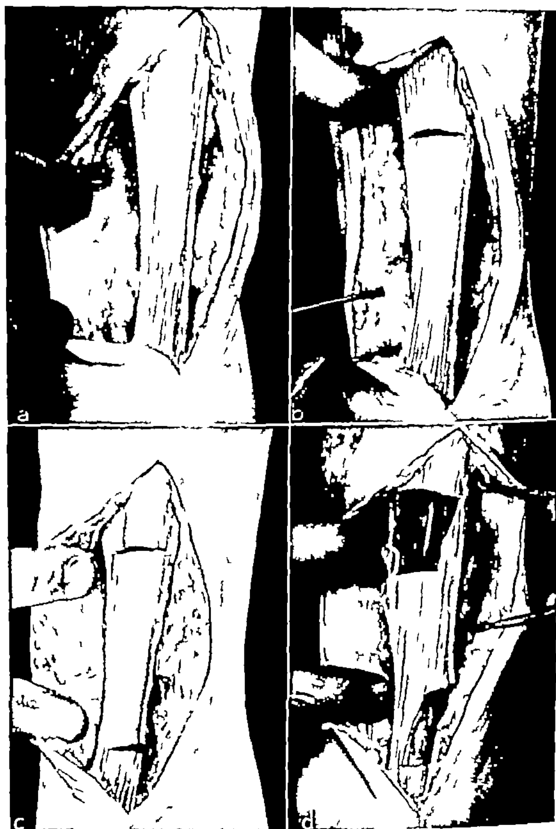


Fig. 692.—Technic of lengthening Achilles tendon by section of posterior two-thirds proximally and medial two-thirds distally (From Cummins, E. J et al.: Surg., Gynec. & Obst. 83: 107 1946. Courtesy of Dr E. D. Hauser)

Z-Plastic Tenotomy and Posterior Capsulotomy

The above procedures are often adequate if the calcaneal tendon has not previously been lengthened by operation Surgical lengthening of this tendon is followed by cicatrization, which necessitates a Z-plastic operation in either the anteroposterior or lateral plane We prefer the latter in that the width and contour of the tendon may be preserved with a minimum exposure of cut *surface* If the deformity cannot thus be completely corrected a posterior capsulotomy of the ankle is indicated

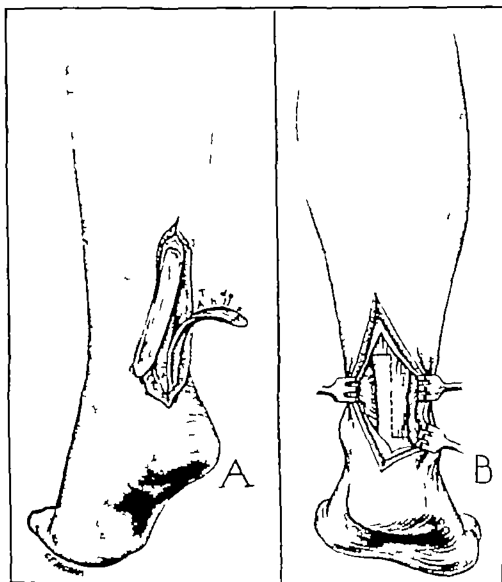


Fig. 614.—Lengthening of tendo achillis *A* Z-plastic severance of tendon from side to side. *B* Division of tendo achillis in anteroposterior plane.

In equinovarus deformities other structures must be lengthened particularly the posterior tibial tendon to obtain adequate correction (see Brockman operation p 1567)

Technic.—The patient is placed on the unaffected side or in the prone position An incision three to four inches in length is made medial to the tendo achillis, the sheath is incised and its edges are caught with small hemostats, that an accurate closure may be made later With a scalpel, the tendon is severed in half from side to side longitudinally beginning proximally

and continuing distally for three or four inches. The proximal cut is completed on the dorsal aspect and the distal cut on the anterior aspect of the tendon, leaving the dorsal flap of the tendon attached to the os calcis and the anterior flap attached to the gastrocnemius and soleus muscles. After division of the tendo achillis, the foot, as a rule, can be fully dorsiflexed by manual force and the tendon thus elongated The cut edges are apposed and sutured together without tension. The only exposed raw area of the tendon is in the superior portion of the wound this is covered when the subcutaneous fat is sutured. By this procedure, the possibility of adherence of the tendon to the skin is reduced to a minimum, as the distal and more superficial portion of the tendon presents a smooth uninterrupted external surface while the raw area is proximal and relatively deep to the skin.

To lengthen the tendon in the anteroposterior plane, the division is made in the midline longitudinally One of the halves is severed laterally at the *proximal end, and the opposite half medially at the distal end*

If the posterior capsule of the ankle is contracted, full dorsiflexion may not be possible by division of the tendo achillis alone dissection is then made in the midline posteriorly and the flexor hallucis longus tendon which passes obliquely across the capsule on the medial side, is retracted inward. The nerves, vessels, and tendons behind the internal malleolus are also protected. Thereafter the capsule may be visualized and incised transversely to permit full dorsiflexion.

After Treatment.—Before applying the cast, the skin over the tendo achillis just above the heel must be carefully inspected with the foot in the fully corrected position. If the skin is blanched or under excessive tension, the edges of the wound may slough exposing the tendon or the sloughing may even involve a portion of the tendon causing fibrosis and adding to the danger of recurrence of the deformity Subsequent ulceration of the low grade scar tissue is not uncommon. When the skin is taut, the foot may be partially corrected and maintained in a splint or cast until the acute reaction subsides. By this method sloughing following further correction is avoided

A circular plaster cast is applied from the midthigh to the toes, with the knee and ankle at 90 degrees. At the end of six weeks, the cast is removed passive and active exercises are instituted and walking is allowed in a brace which permits dorsiflexion but prevents plantar flexion.

In recurrent equinus deformity for which operation has previously been performed scar tissue may be excessive involving the skin and subcutaneous tissues as well as the deeper structures. This not only provides a poor field for surgery but increases the likelihood of further recurrence of the deformity Following correction of the equinus, sloughs from interference with the circulation are common. If the deformity is extreme excision of the superficial scar tissue and replacement by a full thickness pedicle skin graft may be advisable prior to corrective measures.

Intra-Articular Ankylosis of the Ankle in Equinus

Osteotomy

A serviceable foot may be restored by cuneiform osteotomy through the ankylosed joint and correction of the equinus deformity The procedures *for correction of associated cavus, varus, or valgus deformities of the foot are described in Chapter XXII.*

Technic.—An incision five inches in length is made over the anterolateral aspect of the foot and ankle By subperiosteal dissection, the joint is exposed without injury to the extensor tendons or dorsalis pedis artery With a one half inch osteotome a cuneiform section of bone its base anteriorly, is re moved through the site of the former joint In extreme equinus deformity lengthening of the tendo achillis and division of the posterior capsule will permit correction of the deformity without resection of a sufficient amount of bone to produce an undesirable degree of shortening The foot is forcibly dorsiflexed until the most serviceable position for function namely 90 degrees is restored The osseous surfaces at the site of the osteotomy should be apposed when the ankle is in this position

After Treatment.—The correction is maintained by a boot cast and a window is cut out over the dorsum of the foot to allow for swelling At the end of three weeks a walking boot cast is applied and weight bearing resumed with crutches. Eight weeks postoperatively the cast is removed and a rein forced leather lacer brace which extends from the level of the tibial tubercle to the toes, is fitted and worn until union at the osteotomy site is complete

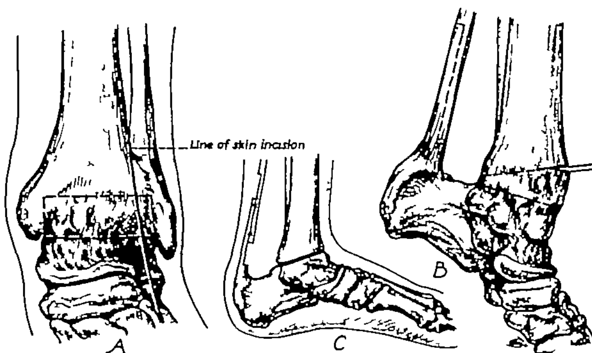


Fig. 691.—Correction of equinus deformity with bony fusion of ankle joint. *A* Line of skin incision and outline of bone to be removed. *B* Cuneiform osteotomy with base anteriorly Z-plastic division of tendo achillis. *C* Foot and ankle in satisfactory weight bearing position.

KNEE

Extra-Articular Ankylosis in Extension

Ankylosis of the knee whether intra-articular or extra articular may take place with the knee in complete extension in flexion alone, or in flexion, valgus, and external rotation. In extra articular ankylosis, some degree of motion may be preserved the roentgenogram may reveal an apparently normal joint space.

Following simple or compound fractures of the femur or extensive soft tissue wounds of the thigh scarring of all or a part of the quadriceps mechanism may lead to extra articular ankylosis of the knee in extension To correct this condition Thompson advises excision of the scar tissue to allow the

normal muscles to resume their physiological function. The success of quadricepsplasty depends upon (1) whether the rectus femoris has escaped injury (2) how well it can be isolated from the scarred nonextensible parts of the quadriceps mechanism, and (3) how well the rectus femoris can be developed by active use

Quadricepsplasty (T C Thompson) —The skin and superficial fascia are incised from the proximal third of the thigh to the lower pole of the patella, the location of the incision depending upon the position of the old scars. The deep fascia is divided along each side of the rectus muscle from the upper end of the skin incision to the patella and the rectus is separated and drawn aside from the vasti medialis and lateralis. The anterior knee capsule is then divided

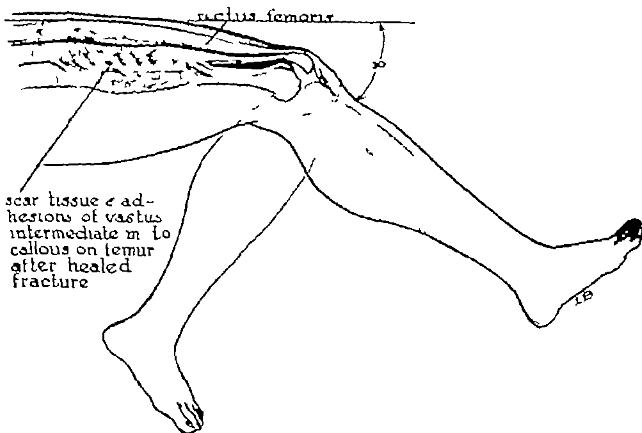


Fig. 691 —Thompson's quadricepsplasty Extensive scarring and fibrosis of vastus intermedius limits motion in knee to 150–180 degrees. (From Thompson, T C J Bone & Joint Surg 26: 366, 1944)

on both sides of the patella for a distance sufficient to overcome the capsular contracture The vastus intermedius, which is usually a scarred band tying the posterior surface of the patella to the femur is excised completely leaving a fibrous and periosteal covering on the anterior surface of the femur If the rectus has been destroyed by the original injury a new rectus tendon may be created by making longitudinal incisions down through the scar tissue in the distal third of the thigh. At this point the knee is slowly manipulated to 70 degrees of flexion, releasing the remaining intra articular adhesions.

If badly scarred, the vasti medialis and lateralis are isolated from the rectus by suture of subcutaneous tissue and fat to the anterior surface of the femur thus creating an artificial intermuscular septum and eliminating all scarred

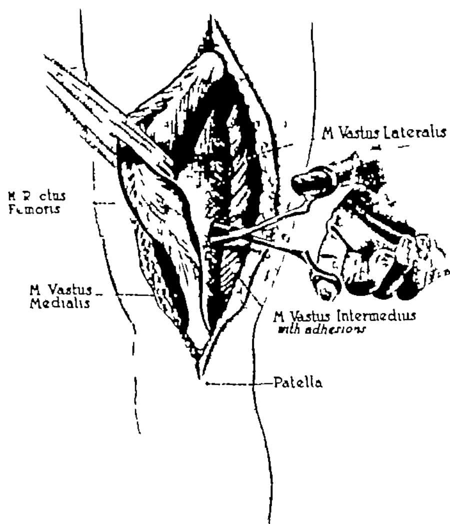


Fig. 697.—Same as Fig. 696. Exposure of quadriceps mechanism through anterior incision. Rectus femoris retracted to expose scarred vastus intermedius. (From Thompson, T. C.: J. Bone & Joint Surg. 26: 366, 1944.)

M Rectus Femoris

Excised portion of M Vastus Int.

Fig. 698.—Same as Fig. 696. Vastus intermedius dissected free and excised. (From Thompson, T. C. J Bone & Joint Surg. 26: 366, 1944.)

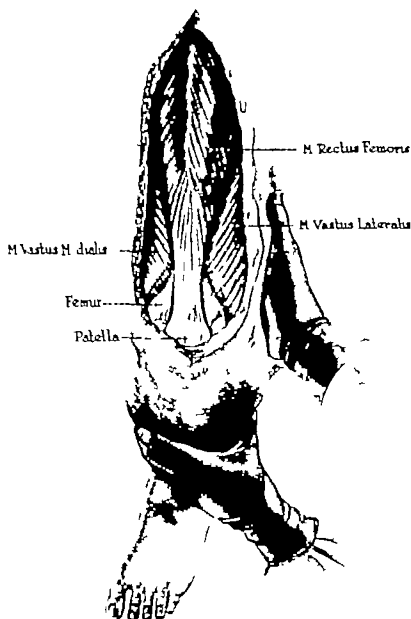


Fig. 699.—Same as Fig 696. Vastus lateralis and vastus medialis freed from patella, and knee forcibly flexed. (From Thompson, T C. J Bone & Joint Surg. 26: 366 1944.)

muscle from the remaining quadriceps mechanism. If relatively normal, the vasti are reunited to the rectus as far distally as the lower third of the thigh.

After Treatment —The extremity is immobilized in a Thomas splint with Pearson attachment (p 76) and balanced traction is continued for three weeks. Passive and active exercise of the knee is begun immediately and continued until a satisfactory range of active motion against resistance is restored.

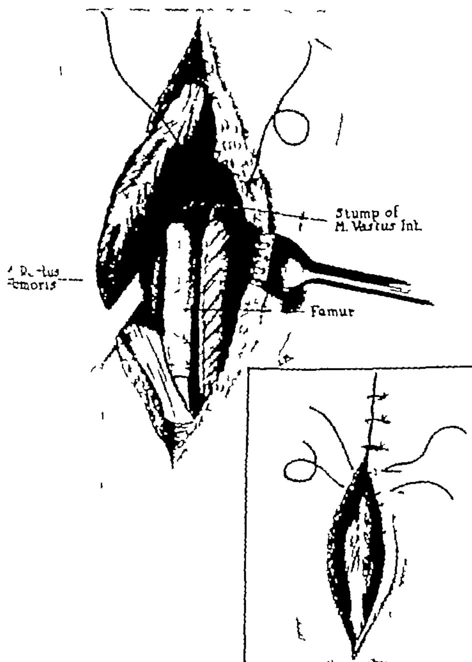


Fig. 700 —Same as Fig 486. Soft tissue interposed between rectus femoris and scarred vastus lateralis Insert shows closure. (From Thompson, T C J Bone & Joint Surg. 26 366 1944.)

Bennett employs a technic whereby the entire quadriceps tendon is released from its muscular attachments dropped to a lower level, and resutured.

Technic (Bennett) —*A straight* incision is made on the anterior surface of the thigh extending upward from the middle of the patella to the juncture of the lower and middle thirds of the thigh, and the subcutaneous tissue and

fascia are divided The distal portion of the quadriceps tendon is released by longitudinal incisions on each side of the tendinous section of the rectus femoris muscle These parallel incisions are then carried deeper to include the tendinous section of the vastus intermedius muscle and to separate both rectus femoris and vastus intermedius from the vastus internus and externus muscles. Proximally, the longitudinal incisions are joined by a transverse incision at the upper portion of the suprapatellar pouch The tendon mass is further dissected from the underlying tissue until completely detached The knee may now be fully flexed provided there is no interference with the motion of the joint itself Intra articular adhesions which restrict flexion may be severed The tendon is sutured to the muscles at a point one inch or more distal to its former attachment and the knee is immobilized in full flexion.

After Treatment.—See above

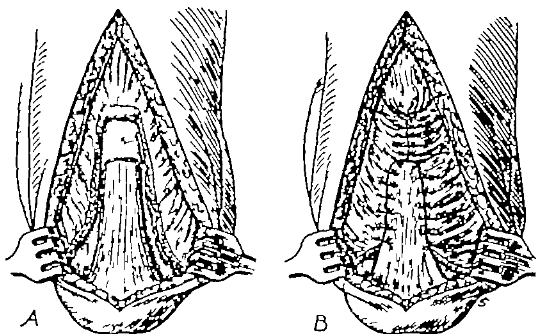


Fig. 701.—Bennett operation for lengthening of quadriceps tendon. *A*, Quadriceps tendon released from muscular attachments. *B*, Tendon sutured at lower level. (Redrawn from Bennett, George E.: J Orthop. Surg. 1 630 1919)

Extra-Articular Ankylosis of the Knee in Flexion

Flexion contracture of the knee is much more common than extension con traction, and is often associated with subluxation and external rotation of the tibia. This position is induced by the combined action of the hamstring ten dons, which pull the tibia backward, and the biceps muscles and iliotibial band attached to the head of the fibula, which rotate the leg outward. As a consequence all the soft tissue structures of the popliteal space are con tracted.

Flexion contractures are amenable to conservative methods of correction, the amount of extension obtainable by these means depending upon the sever ity and duration of the deformity Traction of either the balanced suspension or Buck s extension type, and splints or braces designed to produce gradual ex tension of the knee are widely employed The procedures may be used pre-operatively to diminish the extent of anticipated surgery and postoperatively to improve the results. Regardless of the method of correction of the contrac ture, it should always be borne in mind that the peroneal nerve is more suscep tible to injury by stretching than is the popliteal artery or its branches, and

the appearance of irritative symptoms along its distribution is a signal to proceed with caution. In some cases, prolonged or permanent paralysis has followed as little as 20 degrees of correction of a flexion contracture of the knee, particularly if a recurvatum is purposely created by osteotomy

The following operation is a modification of a technic described by Putti in 1921

Posterior Capsulotomy

Technic.—With the patient in the prone position, the skin and superficial fascia are incised in the midline for a distance of six inches. The medial and lateral aspects of the posterior capsule are exposed by separate approaches through the deep structures

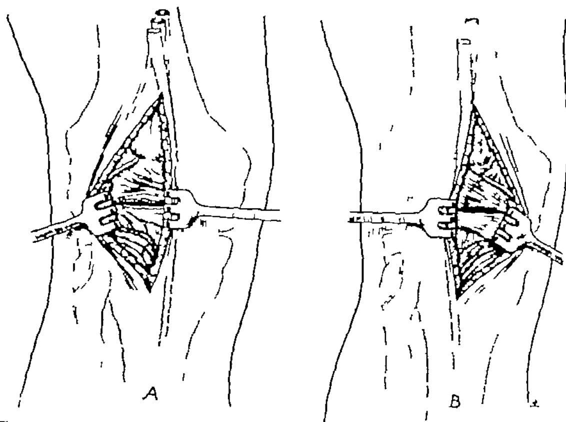


Fig. 702.—Posterior capsulotomy for flexion contracture of knee. Heads of gastrocnemius muscle incised transversely over femoral condyles. Capsule divided transversely

Dissection is carried between the subcutaneous tissue and deep fascia to the lateral aspect of the popliteal space, and the deep fascia is incised longitudinally The biceps tendon and common peroneal nerve are isolated and retracted outward exposing the lateral head of the gastrocnemius muscle. The popliteal vessels and nerves which lie in the midline are retracted medially and the lateral head of the gastrocnemius, the lateral half of the posterior capsule and the attachment of the posterior crucial ligament are severed under direct vision.

Dissection is continued between the subcutaneous tissue and deep fascia to the medial aspect of the popliteal space. The deep fascia is incised exposing the lateral aspect of the semimembranosus and semitendinosus muscles these structures are retracted medially The popliteal vessels and nerves are retracted laterally and the medial head of the gastrocnemius muscle and medial half of the capsule are severed. If the hamstring tendons are not contracted

the knee usually may be extended by gentle force after this procedure Under no circumstances should excessive force be applied During extension, there is an audible rupture of some of the fibrous adhesions.

Occasionally, the biceps, semitendinosus, semimembranosus tendons, and the iliotibial band are unduly contracted The tendons are lengthened in a Z-plastic manner, the iliotibial band and lateral intermuscular septum are divided. If rotation and valgus of the tibia on the femur are present, additional procedures as described by Yount (p 1032) are necessary

In the final closure, only the subcutaneous tissue and skin are sutured.

After Treatment.—If there is no disturbance of the circulation, as determined by examination of the toes, and the flexion deformity was of mild degree the extremity is immobilized in a plaster cast from the toes to above the crest of the ilium, the knee being maintained in complete extension. The cast is bivalved from the upper thigh to the toes to prevent impairment of the circulation. At the end of ten days to two weeks, the cast is removed, a posterior splint is applied and physical therapy instituted The splint is worn for three weeks, then replaced by a drop ring brace which holds the knee in full extension on walking but permits flexion on sitting The brace is retained until the patient can fully and actively extend the knee. As a precaution against recurrence a night splint is worn for at least six months.

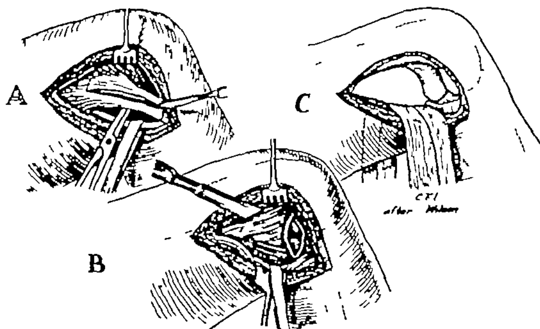


Fig. 703—Philip D. Wilson operation for flexion contracture of knee. *A* Z-plastic lengthening of biceps tendon. Peroneal nerve retracted. *B*, Posterolateral compartment of joint exposed attachments of gastrocnemius muscle and joint capsule stripped subperiosteally from femur *C* Through medial incision, subperiosteal stripping procedure completed from this side. (Redrawn from Wilson, Philip D. J Bone & Joint Surg. 11: 40 1929)

If the deformity is excessive, full correction is secured at operation although maintenance of full correction by a cast is not desirable. Instead, Buck's extension is applied and continued for a period of two to three weeks postoperatively beginning with the knee in 150 to 135 degrees flexion and extending gradually until correction is complete By this method, injury to the nerves and vessels is reduced to a minimum. The extremity is placed in a cast thereafter and treatment is carried out as described above

Technic (Philip D Wilson).—An incision five inches in length is made over the lateral aspect of the knee joint from just above the condyles of the

femur to the head of the fibula. The iliotibial band is divided transversely two inches proximal to the joint The biceps tendon is then isolated for a distance of four inches from its insertion into the head of the fibula, the peroneal nerve is retracted, and the tendon split in a Z-plastic manner, to be sutured later in a lengthening position After identification of the lateral condyle of the femur posteriorly an incision is made through the capsule at this point into the posterior compartment of the knee. With a periosteal elevator, the capsule is stripped upward from the posterior aspect of the femur The incision is then extended upward over the lateral condyle of the femur the outer head of the gastrocnemius muscle is separated, and the subperiosteal dissection carried three inches above the joint and inward to the midline of the femur

A medial incision is next made from above the adductor tubercle to just below the joint line. The posteromedial margin of the capsule is incised and subperiosteal dissection is carried out on the inner side as on the outer A long, broad strip of gauze is passed through the capsule from side to side, to serve as a retractor With the knee in acute flexion and the posterior structures retracted, the tight capsular structures in the region of the intercondylar notch are freed by subperiosteal dissection. If the peroneal nerve appears taut after full extension of the knee, the nerve is completely freed by dissection around to the neck of the fibula.

After Treatment.—See above

Yount, in 1926 called attention to the role of the tensor fasciae femoris muscle in producing flexion and abduction contractures of the hip, flexion contracture of the knee, and abduction and external rotation of the tibia on the femur This combination of deformities is frequently observed in poliomyelitis. Unless the deformity is severe and of long standing he advocates division of the iliotibial band at the knee, thus releasing recent abduction, flexion contracture of the hip and flexion deformity of the knee. Deformities of the hip of long standing require more extensive surgery (p 1039) as a supplement to this technic.

Technic (Yount) —The fascia lata is exposed through a longitudinal incision. *The iliotibial band is divided laterally to the biceps tendon and medially to the anterior surface of the thigh, at a level one inch proximal to the patella.* Fitchett advises excision of a two- to three-inch section of the iliotibial band and a similar segment of the lateral intermuscular septum at this level. Prior to closure, the completeness of division of all tight bands is determined by palpation If flexion and genu valgum are extreme, the biceps tendon is lengthened.

After Treatment.—(See Irwin After Treatment, p 1377)

For a severe deformity at the knee without a flexion deformity of the hip the following procedure is employed Beginning three and one-half inches above the joint over the biceps tendon, the incision is carried anteriorly and distally over the iliotibial band to the outer border of the patella, and ended on the outer surface of the leg just below the fibula. After reflection of this flap of skin the fascia lata and biceps are exposed at their attachments below the knee. The biceps tendon is lengthened, and all ligamentous structures, as well as the attachment of the iliotibial band, are freed by subperiosteal stripping from the lateral condyle of the tibia beginning at the tubercle and extending upward to the joint level. The intermuscular septum is denuded and stripped from the femur for a distance of one centimeter A portion of the

external lateral ligament is detached from the head of the fibula, with c to avoid the peroneal nerve The knee is then forcibly extended and rota internally

Intra-Articular Ankylosis of the Knee in Flexion

Transverse Supracondylar Osteotomy of the Femur

In this procedure deformity is corrected indirectly by the creation o compensating deformity in the opposite direction. The measure is appropri as a rule, only when the deformity is slight and interference with the joint force or surgery is contraindicated as, for example in quiescent tuberculo The contour and mechanical status of the extremity may be improved, but be far from normal In children the osteotomy site must be well proxi to the epiphysis injury to this structure will further complicate the deform by impairing growth

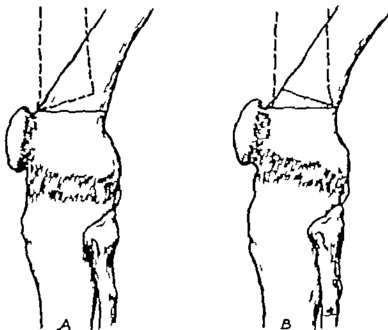


Fig. 104—Supracondylar osteotomy for ankylosis of knee in flexion. *A*, Trans osteotomy Dotted line represents femur after correction, with subsequent wedge-shaped s base posteriorly. *B* Cuneiform osteotomy Section of bone removed indicated by shaded Dotted lines indicate position of bones after osteotomy with complete apposition of raw faces of fragments.

Technic.—An incision one inch in length is made over the lateral aspec the thigh just above the external condyle of the femur and dissection is tinued through the fascia lata and vastus lateralis muscle to the bone. *osteotome is inserted* and turned to cut *transversely* and the *femur is div* laterally and posteriorly through two-thirds of its thickness. By man force a greenstick fracture is created in the remaining portion, and the formity corrected If the flexion contracture is *more than* 135 degrees, o tenotomy of the hamstring tendons may be advisable *prior to osteoto*

After Treatment.—The normal alignment of the extremity is restored nearly as possible and a plaster cast is applied from the toes to above the c of the ilium At the end of three weeks, the cast is changed to permit further correction of the deformity *The second cast is removed* eight we postoperatively and a brace without a joint at the knee is applied to maint the corrected position.

Following the Osgood procedure, the brace is omitted active motion and quadriceps exercises should be permitted as early as possible, and should be continued intelligently and conscientiously until the preoperative arc of motion has been regained

V Osteotomy

For ankylosis of the knee in flexion, the telescoping V-osteotomy described by V P Thompson offers a simple and effective correction. In the lateral plane, the osteotomy is carried out obliquely the anterior cortex is divided by a V-osteotomy and the posterior cortex transversely Thereafter, an excavation is created in the distal fragment and the pointed conical end of the proximal fragment is introduced into the metaphyseal portion of the distal fragment. By resection of small portions of the proximal fragment, the necessary shortening may be obtained to prevent undue tension on major nerves and vessels

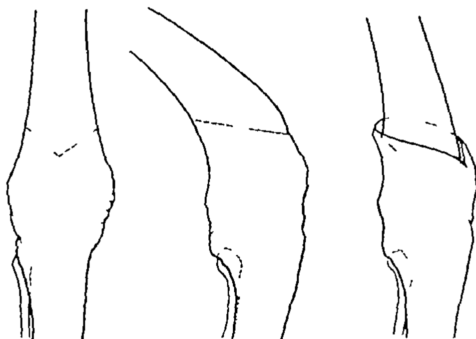


Fig. 703—Thompson's telescoping V-osteotomy (From Thompson, V P: Arch. Surg. 46: 772, 1943.)

Supracondylar Cuneiform Osteotomy of the Femur

When the flexion contracture is 90 degrees or less, a simple transverse osteotomy permits only slight apposition of the fragments after correction. For this reason a cuneiform osteotomy may be preferable in adults.

Technic.—The lateral surface of the thigh is incised longitudinally for three inches, beginning just proximal to the external condyle of the femur To obtain exposure the fascia lata and vastus lateralis muscle are divided and a portion of the muscle is elevated and retracted anteriorly A cuneiform or wedge-shaped section is then removed from the anterior surface of the femur in the region of the metaphysis the angle of the wedge should be approximately *one-half the flexion deformity of the knee.* The gap thus created is closed as the deformity is partially corrected. Complete correction produces a small gap posteriorly yet insures a broader apposition of the osseous surfaces than is possible by a simple transverse osteotomy

Supracondylar Controlled Rotation Osteotomy of Femur (Osgood)

Osgood has devised an ingenious supracondylar osteotomy which is recommended if a functional degree of flexion beyond the range of permanent flexion deformity remains. For cosmetic reasons, the osteotomy should be performed as near the femoral condyles as possible. The mechanics of the procedure prevents posterior rotation of the femoral condyles by the contracture of the gastrocnemius muscle. By this method, complete extension of the knee is practically assured. Adhesions between the adjacent muscles and the callus sometimes tend to shorten the range of motion in the knee to less than the preoperative arc

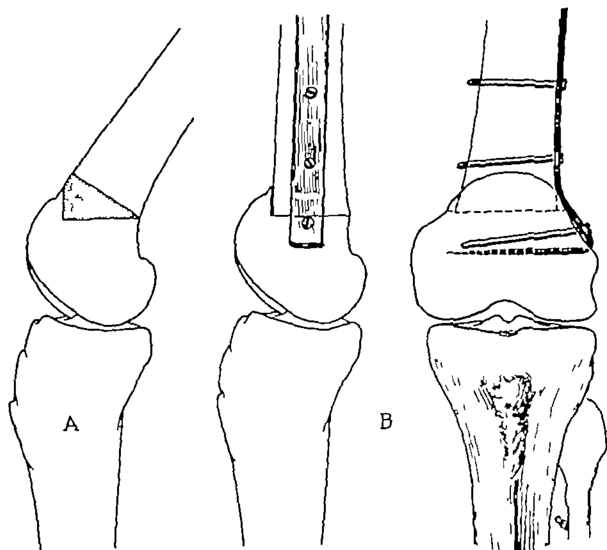


Fig. 708—*Modification of Osgood's supracondylar controlled rotation osteotomy of femur A Shaded area represents section of bone to be removed. B After osteotomy corrected position is maintained by a Blount blade plate.*

Technic (Osgood)—The low supracondylar portion of the knee is exposed by *two one inch incisions one over the medial* and the other over the lateral aspect of the supracondylar ridges. By blunt subperiosteal dissection the anterior medial and lateral aspects of the femur are exposed. The blade of a coping saw is introduced into the wound and the handle is attached (the reciprocating blade of a power-driven saw is ideal) A small quadrilateral segment of bone is next removed the distal surface of the proximal fragment being cut transversely while the proximal surface of the distal fragment is cut on an angle The distal fragment is then rotated forward by "greensticking" the posterior

femoral cortex, until the anterior radius of the angle lies against the anterior surface of the proximal fragment and the posterior ray of the angle lies against the distal end of the proximal fragment This prevents posterior rotation of the femoral condyles

After Treatment.—See above.

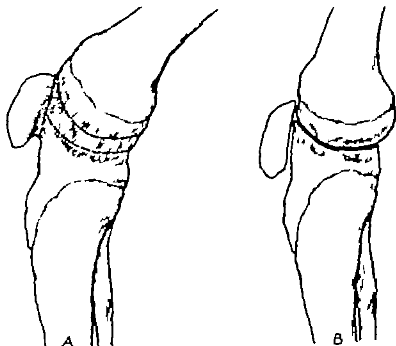


Fig. 707—Intra-articular osteotomy for ankylosis of knee in flexion. *A* Bone divided along dotted lines, conforming to general contour of joint surfaces. *B* After correction of deformity

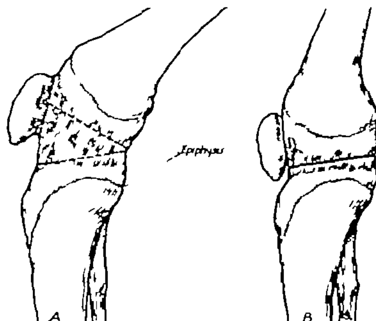


Fig. 708.—Cuneiform intra-articular osteotomy for ankylosis of knee in flexion. *A* Bone divided along dotted lines, wedge-shaped section being removed. *B* After correction of deformity

The above procedure could be modified as follows Through a four-inch lateral incision the supracondylar portion of the lateral femoral condyle is exposed subperiosteally both on its lateral and anterior surfaces. With a reciprocating motor saw, a segment of the femur is excised as above described.

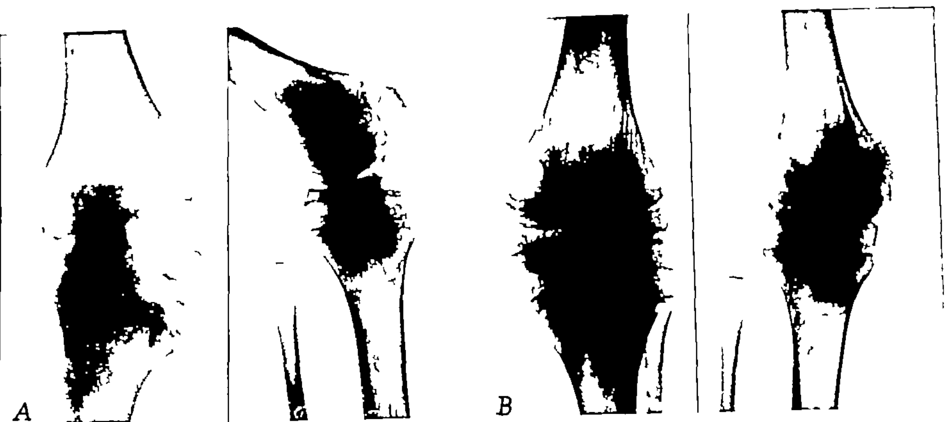


Fig. 769.—A Ankylosis and deformity of knee following pyogenic arthritis. B After arthrodesis. Epiphyses were not violated by surgery

The condyles are then rotated anteriorly A Blount blade plate is next bent at slightly more than a right angle, the blade is inserted transversely through the distal fragment in the position of correction and the plate is fixed to the femur by screws. If internal fixation appears adequate, the extremity should be immobilized in a long leg splint with the knee in the corrected position If internal fixation is not adequate at the time of operation a long leg cast is applied with the knee extended and is worn for four weeks.

These rather large plates near joints interfere with restoration of motion and should be removed as soon as the osteotomy is solid

Intra-Articular Osteotomy

Frequently patients are observed with an intra-articular ankylosis of the knee in flexion so extreme as to prevent weight bearing If arthroplasty is contraindicated because of the age or occupation of the patient, intra articular osteotomy or severance of the osseous ankylosis and correction of the flexion contracture offer an efficient weight bearing extremity In children, the epiphysis must be protected in order to obviate disturbances in growth.

If the joint is fused in extreme flexion, complete correction at the time of operation is not advisable. Removal of the necessary amount of bone at one procedure will cause an undesirable degree of shortening, or, if the minimum amount of bone is excised and the joint is forced into extension, unpleasant vascular or neurologic complications may follow Thus the deformity should be only partially corrected at the time of osteotomy, and conservative measures which gradually stretch the contracted structures on the posterior surface of the joint should then be carried out (Figs. 707, 708)

Technic.—A long anteromedial incision is made, conforming to the medial border of the quadriceps, and to the patella and patellar tendon. The ankylosis between the patella and femur is severed and the soft structures stripped subperiosteally from the anterior surface of the joint. If the deformity is of only moderate degree, an osteotomy parallel to the normal contour of the condyles of the femur may be employed. In extreme flexion, a wedge-shaped section of bone is removed, principally from the posterior portion of the femoral condyles, in order to conserve the length of the femur In children with extreme flexion deformity full correction may not be possible without invasion of the epiphysis. In this event, the deformity is only partially corrected by excision of bone, and this is followed two weeks later by posterior capsulotomy and lengthening of the hamstring tendons.

After Treatment.—If the deformity is corrected within 10 to 15 degrees of complete extension, the extremity is immobilized by a single spica cast extending from the crest of the ilium to the toes. If the deformity is only partially corrected, a hinged Thomas splint is applied to maintain the limit of possible extension. After the postoperative reaction subsides, conservative measures, such as Buck s extension or special apparatus, are employed to complete the correction The knee is then fixed in the most serviceable position by means of a cast until ankylosis recurs.

HIP

In extra articular contracture of the hip, the deformity is usually either flexion-abduction-external rotation or flexion-adduction internal rotation depending upon the structures involved Unlike the knee, the hip is never main

tained in a functional position by contractures of the extra articular structures. With deformities of long standing the obliquity of the pelvis may enforce a fixed lumbar scoliosis, particularly following poliomyelitis. For the handling of these difficult cases, the reader is referred to Chapter XXII

Extra Articular Ankylosis of the Hip in Flexion and Abduction

Irwin points out that because of inability to fix the pelvis, conservative measures to correct this deformity are notoriously unsuccessful. The role of the iliotibial band in the production of flexion-abduction deformity of the hip has been well explained (p 1372) For recent mild contractures the Yount procedure (p 1032) may be adequate Old deformities with adaptive shortening of numerous structures require additional and more extensive surgery as described below

Transference of the Crest of the Ilium

Occasionally deaths have occurred following forceful attempts to correct completely flexion contractures of the hip without release of all contracted structures. Campbell devised a technic based upon the Soutter operation with new features, which permits full correction of the deformity This procedure, transference of the crest of the ilium is particularly suitable for extreme flexion abduction contracture following poliomyelitis.

Technic (Campbell) —The skin is incised along the anterior one-half or two-thirds of the crest of the ilium to the anterior superior spine thence distally two to four inches on the anterior surface of the thigh. The superficial and deep fasciae are divided to the crest of the ilium With an osteotome the outer one fourth of the crest is chiseled through from before backward and the attachments of the tensor fasciae femoris and the gluteus medius and minimus muscles are stripped subperiosteally from the outer wing of the ilium down to the level of the acetabulum The proximal portion of the sartorius muscle is then separated from the tensor fasciae femoris muscle The anterior superior spine is removed with an osteotome, and the sartorius muscle which arises from this process, is allowed to retract distally and posteriorly The anterior border of the ilium is next denuded down to the anterior inferior spinous process. Release of these contracted structures will often permit the hip to be hyperextended without increasing the lordosis of the lumbar spine this is a most important point as correction is often more apparent than real If the hip cannot be completely extended without increasing the lordosis, other contracted structures must be sought

Dissection is now carried along the inner surface of the crest of the ilium and the iliacus muscle is detached subperiosteally from the inner table The attachment of the rectus femoris muscle to the anterior inferior spine of the ilium is freed and the reflected head of this muscle severed along the anterior margin of the acetabulum If necessary the contracted capsule of the hip joint is severed obliquely from above downward and, as a last resort the iliopsoas muscle is released from its attachment to the lesser trochanter by tenotomy After full correction of the deformity the redundant portion of the denuded rim of the ilium is removed with an osteotome. A tract of bone one inch wide is then denuded on the wing of the ilium two inches below and parallel to the former crest and the transferred crest is approximated to this area The superficial fascia on the upper side of the incision is stitched to the deep fascia on the lower side bringing the skin incision one inch below the edge of the ilium and thus avoiding possible osseous pressure

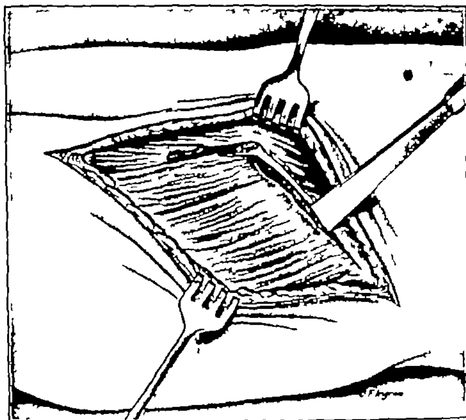


Fig. 710.—Transference of crest of ilium for flexion contracture of hip. Bony origin of sartorius muscle and origin of tensor fasciae femoris and gluteus medius muscles detached from ilium.

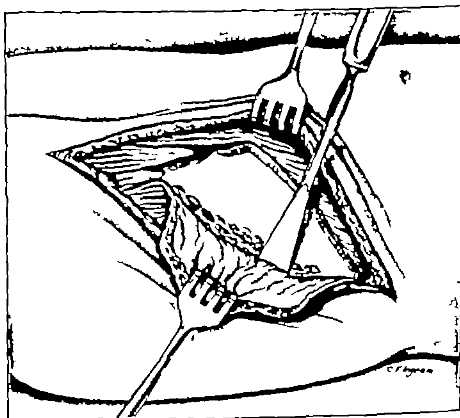


Fig. 711.—Same as in Fig. 710. Attachment of rectus femoris muscle divided. Muscles stripped subperiosteally from lateral wing of ilium. Deformity corrected. Lateral surface of ilium roughened at site of new attachment of crest of ilium.

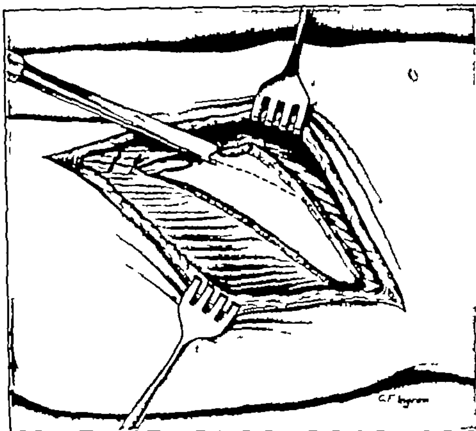


Fig. 711.—Same as in Fig. 710 Redundant portion of ilium removed.

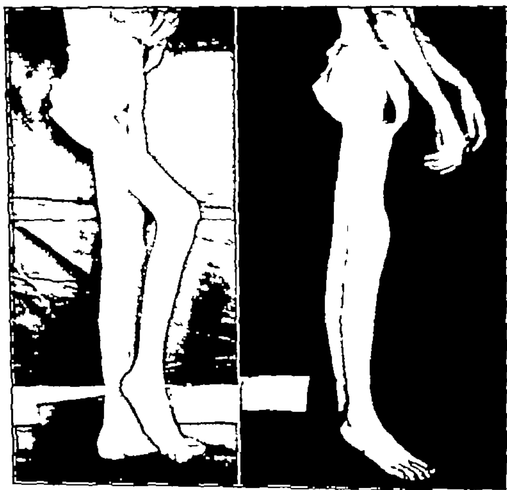


Fig. 713.—Flexion contracture of hip before and after transference of crest of ilium.

After Treatment.—The hip is placed in hyperextension and approximately 170 degrees abduction, and is immobilized in a plaster cast which extends from the toes to the nipple line on the affected side and to the knee of the opposite extremity After three or four weeks, the cast is removed and suitable fixation instituted. Support may be unnecessary during the day when the patient is on crutches at night however Buck s extension, or a splint with a chest and pelvic band which extends to the toes on the affected side and to the knee on the opposite side, should be applied. If the deformity is the result of poliomyelitis, appropriate braces should be fitted.

In severe deformities, even though all structures have been divided, the hip should not be immobilized in a completely corrected position Rather, correction should be secured gradually, as suggested by Irwin (p 1377)



Fig. 714 —Subcutaneous adductor tenotomy Tenotome inserted perpendicularly with blade parallel to longitudinal axis of extremity after one is certain of proper placement of knife by palpation, blade is faced medially and tendons are cut.

Technic (Soutter)—The joint is approached through an anterior iliofemoral incision (p 146) The subcutaneous tissue is retracted and the entire thickness of the fascia divided at a right angle to the skin incision, from the anterior superior spine back to the greater trochanter The skin incision *is next retracted to expose the anterior superior spine*. By means of an osteotome, the attached muscles and fascia are separated from the anterior superior spine subperiosteally on the inside the outside, and below

The tissues are drawn down as the hip is hyperextended If the tension is too great the periosteum and soft structures from that part of the pelvis

elow the anterior spine are pushed downward by means of gauze or a blunt issector

After Treatment.—See above

Extra Articular Ankylosis of the Hip in Adduction and Internal Rotation

Adduction, internal rotation deformity of the hip from contracture of the oft tissues usually is observed in spastic paralysis. Corrective procedures for his condition are therefore described in Chapter XXIII

Surgical procedures for adduction contracture are utilized usually, in con unction with other corrective measures For example, if the deformity is adduc ion flexion, transference of the crest of the ilium may be combined with abductor enotomy as described below Rather than divide the tendons blindly by sub- utaneous tenotomy, a small medial longitudinal incision may be used for lirect visualization of these structures

Adductor Tenotomy—The hip is abducted as far as possible in order o cause the contracted muscle to stand out prominently With a tenotomy nife inserted vertically, its cutting edge toward the medial surface of the high just lateral to the adductor longus and gracilis muscles these structures re severed subcutaneously immediately distal to their origins on the pubic one. The extremity is then forced into extreme abduction 50 per cent of ormal abduction is considered sufficient if undue resistance is encountered. If correction is incomplete from osseous changes in the hip or from extreme oft tissue contractures of long standing subtrochanteric osteotomy may be necessary

Intra-Articular Ankylosis of the Hip in Flexion or Adduction

Trochanteric Osteotomy

If operations for restoration of motion are contraindicated as in tuber culosis or in osteomyelitis adjacent to the hip joint, any one of three funda mental types of trochanteric osteotomy may be employed. These procedures are employed alone or in connection with other operations, as adductor tenotomy The Gant procedure is a transverse open wedge osteotomy the Whitman is a transverse cuneiform or closed wedge osteotomy and the Brackett is a circular or ball and socket osteotomy These are basic operations which have been in use for many years and have been modified by many surgeons from time to time as improvements in technic have been developed

The chief advantages of the Gant procedure lie in its simplicity and in the fact that the lower extremity is lengthened. On the other hand, the resulting edge-to-edge contact materially limits stability and in adults, delays union of the osteotomy

Technic (Gant)—The trochanteric area of the femur is exposed through a five-inch lateral incision (p 179) A drill is inserted perpendicular to the long axis of the femur at a level slightly proximal to the lesser trochanter and its position is verified by roentgenograms With an osteotome the femur is di vided transversely at the level of the drill point the extremity is placed in the corrected position and a Blount blade plate is inserted as for a subtrochanteric fracture (p 426)

After-Treatment.—Immobilization is effected by a cast extending from the nipple line to the toes on the affected side and to the knee on the opposite side. At the end of three weeks, the cast is bivalved stitches removed and a new cast applied. Complete fixation is maintained for eight weeks After mo-

tion in the knee and muscle power are adequate, the patient is allowed up with crutches. After roentgenograms demonstrate solid union, unprotected weight-bearing is resumed. In children, deformity may recur after several years of growth necessitating a second osteotomy

The Whitman osteotomy is advantageous in that the broad bony contact provides stability and union is usually prompt. *Its disadvantage is that an additional shortening of the extremity is imposed.*

Technic (Whitman)—The operative field is exposed through a five-inch lateral longitudinal incision (p 179) With an osteotome, a cuneiform wedge of bone is outlined, the base of the wedge being opposite the direction of the deformity and its apex at the level of the proximal border of the lesser trochanter The size of the segment to be removed is proportionate to the degree of deformity (Tracings of the preoperative roentgenograms and paper cutouts provide a method of accurately determining the angles of the cuts) After removal of the wedge, the distal fragment is abducted, with the defect closed, if the operation is properly performed the alignment of the extremity should be correct. A Blount blade plate is then inserted as for subtrochanteric fractures.

After Treatment.—See above.

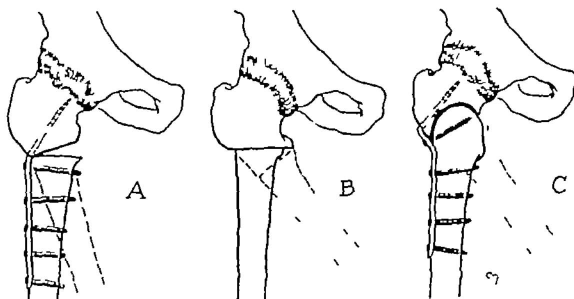


Fig 715.—Trochanteric osteotomy *A* Open wedge osteotomy maintained in position by internal fixation (Gant) *B* Closed cuneiform wedge osteotomy (Whitman) *C* Ball and socket osteotomy with position maintained by Blount blade plate (Brackett)

Stability and prompt union, without additional shortening are *desirable* features of the Brackett technic. It has the disadvantage of being rather formidable in that extensive dissection is required. Further a stable and accurate osteotomy for correction of severe biplane deformities is difficult.

Technic (Brackett)—The anterior surface of the intertrochanteric region, basal neck and upper shaft of the femur is exposed by a straight *five-inch* incision, beginning at the anterior superior iliac spine and extending distally The tensor fascia femoris muscle is retracted laterally while the sartorius and rectus femoris muscles are retracted medially With a narrow osteotome, a curved incision its convexity superiorly and medially is begun on the lateral side of the trochanter and continued to the juncture of the lesser trochanter with the neck. The osteotomy is completed and the distal fragment is abducted, as it rotates within the hollow of the proximal fragment the deformity

is corrected If the degree of adduction is slight, the lateral margin of the bone incision should be level with the medial margin. If the deformity is severe, the lateral margin of the bone incision should be placed slightly more proximal. In severe flexion deformity, the anteroposterior line of incision should be directed so as to provide a slight roof over the anterior edge of the proximal fragment.

After Treatment.—See above.

This procedure may be modified to advantage by the use of the Watson Jones or Callahan incision for exposure (p 149), the reciprocating motor saw for the osteotomy and internal fixation as for trochanteric femoral fractures (p 426)



Fig. 716.—Satisfactory weight-bearing hip following osteotomy for adduction deformity with ankylosis of hip. Line indicates extent of deformity prior to operation.

Torsion Deformities of the Tibia and Femur

Primary rotation deformities of the tibia and femur arise from disturbances in growth as a result of metabolic disturbances or infectious diseases, or congenital or static anomalies of the bones and joints. They are also frequently secondary to muscle imbalance as observed in spastic or infantile paralysis. The technics of rotation osteotomies of the tibia and femur are described in the chapter on Poliomyelitis.

Extra-Articular Contractures of the Jaw

Cicatricial contractures of the jaw wherein the alveolar processes are bound together by a thick mass of scar tissue, may be induced by gangrenous ulceration of the mouth (noma) or burns from caustic solutions. When, in addition, the cheeks are bound into the mass of scar tissue or defects of the

cheek remain after release of the extra-articular structures, extensive skin grafts may be necessary to restore the buccal lining. Such procedures are within the province of the plastic surgeon. For the more simple contractures, wherein the alveolar processes are principally involved, the following technic may be sufficient.

The cicatricial bands are divided systematically from before backward with a tenotomy knife and the scar tissue resected as thoroughly as possible. Bony bridges between the alveolar processes, if present, must be severed with a chisel. In order to severe the structures on the inner side, several teeth may have to be extracted. A gag is then inserted and the mouth forcibly opened. Immediately after the postoperative reaction subsides, continuous chewing of gum is encouraged. Wedges or a gag may be inserted between the teeth three to four times daily to further increase the range of motion.

SHOULDER

Extra Articular Ankylosis in Rotation and Adduction

Open surgery for mobilization of the shoulder is not advisable unless the deformity is a fixed severe internal rotation and adduction. Correction may be secured by the operation described by Sever (p. 1506) or by the Lange external rotation osteotomy (p. 1508). Since these procedures are rarely employed except for deformity produced by obstetrical paralysis, they are described in the section on that subject.

Brisement Forcé

Because of the mechanical construction of the shoulder, brisement forcé is most effective for internal rotation and adduction deformities of short duration following traumatic lesions, bursitis or periarthritis. Since the neck of the humerus may be fractured on external rotation, or the shoulder dislocated on abduction, correction must be accomplished with extreme caution. Deep anesthesia should be used.

Technic.—While an assistant provides countertraction at the axilla, the surgeon exerts strong manual traction in the line of the arm with the elbow at a right angle and the shoulder in neutral rotation. No attempt is made to correct the adduction or internal rotation deformity until traction has been continuously maintained for several minutes; the shoulder is then gradually abducted. It is exceedingly important that strong traction be continued on the arm during abduction and until the major adhesions are released. After abduction has been restored, flexion and extension and finally external rotation are forced in a similar manner. We reemphasize: traction is maintained throughout the correction of all component parts of the deformity.

After Treatment.—The shoulder is immobilized by an abduction humerus splint, with the shoulder at 135 degrees of abduction and neutral rotation. Hot packs are applied to the shoulder continuously for the first twenty-four hours and intermittently thereafter until the acute reaction has subsided. Gentle passive motion is instituted on the first postoperative day or as soon thereafter as possible; as the reaction subsides, passive and active motion are begun and continued until a satisfactory range of painless motion is acquired.

ELBOW

As in the knee, periarticular contractures may cause the elbow to be fixed in extension or flexion. Either deformity may be accompanied by pronation contracture of the forearm.

Extra Articular Ankylosis of the Elbow in Extension

Technic.—The triceps aponeurosis is exposed through a long posterolateral incision and dissected free from the muscle forming a tonguelike flap four inches in length. A longitudinal incision is then made down to the posterior aspect of the humerus through the fibers of the triceps muscle and periosteum and these structures are stripped from the humerus. The attachment of the muscle fibers of the triceps to the posterior capsule and to the olecranon process is severed transversely to the joint, thus releasing all contracted tissues. The elbow is fully flexed and placed at 90 degrees. The triceps aponeurosis is then resutured to the muscle at a lower level.

After Treatment.—A posterior splint is applied, holding the elbow at a right angle. Measures to induce function are begun after ten days.

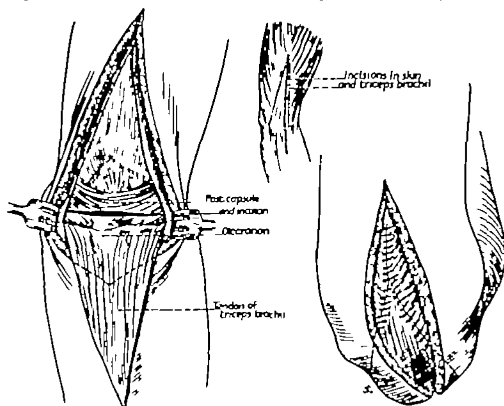


Fig. 717.—Extension contracture of elbow corrected by division of triceps tendon and posterior capsulotomy. Triceps aponeurosis sutured to muscles at a lower level.

Extra-Articular Ankylosis of the Elbow in Flexion

Anterior capsulectomy of the elbow to increase extension is occasionally indicated for a long-standing flexion deformity of the elbow of 120 degrees or less resulting from old supracondylar fractures. The same procedure in conjunction with excision of a deformed radial head is useful following malunited fractures of the head of the radius with a restriction of extension beyond 120 degrees. As a rule this procedure is of limited value in intercondylar fractures because of extensive intra articular and periarticular fibrosis and incongruity of bony surfaces.

Physiological block of the nerves can occur with a minimal amount of stretching or trauma. If the joint is fixed in an acutely flexed position adaptive shortening of the soft tissue structures anterior to the elbow precludes adequate correction by capsulectomy. The osseous structures must ordinarily be shortened by arthroplasty or resection of the elbow before adequate extension can be obtained.

Technic (Wilson).—Using a pneumatic tourniquet an incision is made over the anterior aspect of the elbow parallel to the lateral margin of the biceps tendon, extending two inches proximal and two inches distal to the joint. After division of the anterior fascia the biceps tendon is isolated and divided in a Z-plastic manner. The radial nerve is exposed and retracted laterally. The elbow joint is exposed by a longitudinal incision of the brachialis tendon and anterior capsule. The thickened and contracted mass of anterior capsule is excised completely and any fibrous bands or bony spurs which are encountered in the anterior compartment of the elbow joint are likewise removed. Ordinarily a Penrose drain is inserted into the wound and is left in place for the next forty-two to seventy-eight hours.

After Treatment.—The elbow is immobilized in a position just short of the maximal correction, and the drain is removed after two to three days. Circulation must be constantly watched. The cast is removed after ten to fourteen days and progressive exercises and physical therapy are begun, the elbow being supported in the interim between exercises on a posterior splint or arm sling.

Extra-Articular Ankylosis of the Elbow in Pronation

Measures for correction of pronation contracture of the forearm from spastic paralysis or poliomyelitis are usually combined with tendon transference; these are described elsewhere (pp. 1424, 1499). The following technic is applicable to the more simple contractures unattended by paralysis of the supinator muscles or spasticity of the pronators.

Technic.—An anterolateral incision three inches in length is made over the middle and upper thirds of the forearm, the insertion of the pronator radii teres muscle into the radius is identified and divided, and the forearm is forcibly supinated. A cast is applied to maintain this position.

Occasionally, division of the pronator quadratus muscle may be necessary. In this event, an incision two and one-half inches long is made in the mid-line on the volar surface of the lower third of the forearm. By blunt dissection, the fibers of the pronator quadratus muscle, which run laterally and slightly downward, are located deep to the flexor tendons of the fingers. The muscle is separated from the interosseous membrane and divided transversely at its attachment to the ulna. If necessary, a long section of the interosseous membrane may be incised adjacent to the radius.

After Treatment.—With the forearm in supination, a cast is applied and retained for a period of approximately three weeks. A supinating forearm splint described by Funsten (p. 68) is then fitted and worn until the forearm can be fully and voluntarily held in supination.

In young adults and children, if extensive operations on the soft tissues are not adequate, osteotomy of both bones of the forearm may be carried out. First, the ulna should be divided just above the wrist and an attempt made to correct the deformity. As a last resort, the radius is severed at the middle and lower thirds, and the distal fragments are rotated externally. After correction of the deformity, approximation of the fragments of both bones may be impossible; in this event, the fragments of the radius should be approximated in preference to those of the ulna. Nonunion of the ulna is even desirable, as a greater range of pronation and supination may thus be permitted.

Contour and function are materially improved.

Milch has found that paralytic pronation contractures are characterized by diminution, rather than total loss, of supination. He feels that, by osteotomy

f the proximal ulna and supination of the radioulnar mass, the existing range of motion may be transferred to a more useful arc of function

Technic (Milch) —The proximal subcutaneous portion of the ulna is exposed subperiosteally through a three-inch incision and is divided transversely in its upper third The forearm is then completely supinated and the osteotomy site is fixed by a metal plate and screws as for a fracture (p 364)

After Treatment.—A long arm plaster cast is applied from palm to axilla with the forearm in the supinated position Immobilization is continued until union is firm clinically and by roentgenogram

Extra-Articular Ankylosis of the Elbow in Supination

Severe paralytic supination deformities of the forearm arise from abnormally unopposed muscle pull and ligamentous contracture, and are frequently perpetuated by secondary bony changes. These deformities are usually characterized by bowing of the distal end of the radius with the convexity laterally and bowing of the ulna with the convexity dorsally Ulnar adduction of the hand is often associated In the presence of severe deformity with bony abnormality Blount advocates osteoclasis of the forearm bones.

Technic (Blount) —The affected arm is placed in abduction and external rotation the dorsal surface of the forearm and wrist are placed toward the table, and a padded, sharp wedge is inserted beneath the forearm in this position The surgeon grasps the forearm on each side of the wedge and with a quick straight arm thrust fractures the bones To insure fracture, the bones are bent backward and forward several times The forearm is then pronated between 45 and 90 degrees and this position is maintained by a long arm cast extending from palm to axilla with the elbow at a right angle Immobilization is continued until union is solid clinically and roentgenographically If correction is incomplete further pronation may be obtained by a manipulation under anesthesia two or three weeks later Unless the original deforming factors are corrected the deformity tends to recur gradually in this event repetition of the osteoclasis may be necessary after a few years

WRIST AND FINGERS

Deformities and ankylosis of the wrist and fingers are a specialty unto themselves. The reader may well refer to an excellent book by Bunnell for details Prior to surgery for mobilization and for deformities, conservative measures should be given a thorough trial special splints (Chapter II) frequently aid in restoring a functional position and a satisfactory range of motion and are useful in maintaining a corrected position during convalescence

Carpectomy for Intractable Flexion Deformities of the Wrist

For flexion deformities of the wrist which are too severe to be corrected by ordinary procedures, White advises excision of all of the carpal bones except the pisiform A nice anatomic fitting between the metacarpal bases and the distal dorsal aspect of the radius is obtained By thus shortening the forearm the procedure also provides a relative lengthening of the flexor muscles and tendons. (Also see Volkmann s contracture)

Technic (White) —The carpals are exposed through a mid-dorsal longitudinal incision. The extensor tendons are retracted medially and laterally and beginning at the ulnar side of the wrist the bones are excised in one piece The dissection is carried close to the bones, especially anteriorly The metatarsal

bases and the distal dorsal surface of the radius are apposed without further preparation of their surfaces Triangular sections of the redundant dorsal skin are excised.

After Treatment—A long arm cast is applied with the wrist at 160 to 150 degrees of dorsiflexion, with the forearm in midrotation and the elbow at 90 degrees. The cast is retained for three weeks. If necessary a forearm plaster cast is worn for an additional two weeks and physical therapy is instituted at the end of that time.

Mobilization of the Metacarpophalangeal Joints

Because of the shape of the metacarpal head and the fact that the ligaments are tight in flexion and relaxed in extension, the metacarpophalangeal joints are stiff in a position of extension or hyperextension. Fowler notes that if the collateral ligaments are allowed to remain in a relaxed state bathed in transudates or exudates, the ligaments are shortened glued together and flexion of the joint is blocked. Subsequently, the anterior portion of the head of the metacarpal which is not functioning as a joint surface becames fixed to the anterior capsule. The cartilage may be replaced by scar tissue, and this further blocks flexion. Mere removal of the collateral ligaments under these circumstances will not allow normal flexion. Instead the joint opens by a hinge type action like a book, instead of allowing the phalanx to glide around the anterior surface of the metacarpal head

The pathology described above may be occasioned by splinting of the fingers in extension in the presence of excessive local swelling More commonly such a condition exists in the presence of muscle imbalance, due to the paralysis of the intrinsic muscles, or in any condition of the extensor mechanism which does not allow complete flexion of the finger joints For example imbalance between the extensor tendons and the short flexor group may exist from a fractured metacarpal bone with excessive shortening in this condition the extensors are tight and the intrinsic muscles are put at a disadvantage by the shortening of the distance between their origin and insertion Flexion contracture of the wrist may produce a similar situation

Capsulectomy or capsulotomy to increase the range of flexion in the metacarpophalangeal joint is indicated after a satisfactory trial of physical therapy and traction has failed to produce results over a period of three weeks. If the joint surfaces have been destroyed, the Fowler arthroplasty is the preferred procedure (p 1121)

Capsulotomy should not be employed in combination with any procedure that necessitates extension of the metacarpophalangeal joint following surgery or with a flexor tendon graft. Suffice to say the procedure will not produce a satisfactory range of motion unless the extensor tendons are sufficiently free to allow complete flexion A limited range of motion can be expected to recur with a continuation of muscle imbalance or a metacarpal deformity

Capsulotomy of Metacarpophalangeal Joints (Fowler)—The metacarpophalangeal joint is exposed by incisions in the dorsal web on each side of the joint subsequently the extensor hood is incised by a one centimeter longitudinal incision one half centimeter lateral to the extensor tendon. The extensor hood and intrinsic tendons are retracted and the collateral ligament is completely removed. This is done on both sides of the joint except in cases of intrinsic muscle paralysis in which there is a tendency of the fingers to incline ulnarward in such cases the ulnar inclination should be offset by leaving intact

the collateral ligament on the radial side of the index and little fingers. With the thumb over the base of the proximal phalanx, the bone is pushed forward and simultaneously flexed If, during this maneuver the middle finger joints extend as the metacarpophalangeal joint flexes, the extensor tendon is not free, and this condition must be corrected When the joint angulates or hinges like a book, instead of gliding around the metacarpal head the adherent anterior capsule is blocking the base of the phalanx. This is corrected by stripping the capsule anteriorly from the metacarpal head with a blunt dissecting probe

If after this procedure the extensor tendon subluxates to the side of the joint on flexion, the lateral expansion of the extensor tendon on the side of the subluxation is sectioned or the opposite side is tightened If the latter procedure is used flexion should not be started for one week but should be obtained gradually by traction

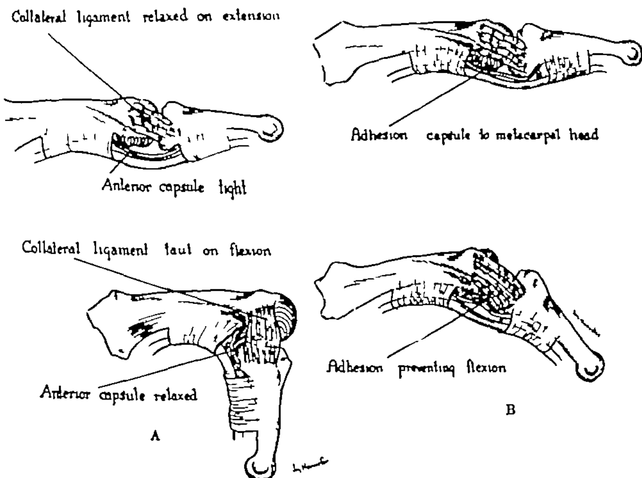


Fig 712.—A Collateral ligaments and anterior capsule in a normal joint. B Flexion of metacarpophalangeal joint limited by short collateral ligaments and adhesion of anterior capsule to metacarpal head. Note hingelike action of joint. (From Fowler S. B. J Bone & Joint Surg. 29: 193, 1947)

After Treatment.—The metacarpophalangeal joints are maintained in a flexed position either by rigid splinting or by traction Should undue pain or swelling necessitate removal of the apparatus, a traction cast should be reapplied at the earliest opportunity and correction gradually instituted Maximum correction of the extended position is maintained for three weeks. Subsequently a removable traction splint is applied for approximately one month Any tendency toward recurrence of the extension deformity indicates a reapplication of the flexion traction splint.

Fowler reports that in over 100 capsulotomies, he has had excellent results, obtaining 80 to 90 degrees of motion provided the mechanics and the soft tissues of the hand are satisfactory

References

Bennett, George E.: Preliminary Report of Lengthening of the Quadriceps Tendon, J Orth. Surg. 1 530 1919

Blount, W P Osteoclasis for Supination Deformities in Children J Bone & Joint Surg 22 300 1940.

Brackett, E. G A Study of the Different Approaches to the Hip-Joint, With Special Reference to the Operation for Curved Trochanteric Osteotomy and for Arthrodesis Boston M. & S. J 166 235 1912.

Brackett, E. G., and Osgood, R. B: The Popliteal Incision for the Removal of Joint Mice in the Posterior Capsule of the Knee-Joint, Boston M. & S. J 165 975 1911.

Campbell, Willis C.: Transference of the Crest of the Ilium for Flexion Contracture of the Hip South. M. J 16 289 1923.

Cummins, E. J., and others The Structure of the Calcaneal Tendon (of Achillis) in Relation to Orthopedic Surgery With Additional Observations on Plantaris Muscle, Surg Gynec. Obst. 83 107 1946.

Ferguson, A. B Thompson, F A. and King, B. B.: A Two-Stage Osteotomy J Bone & Joint Surg 21: 715 1939

Fitchet, S. M. Flexion Deformity of the Hip and the Lateral Intermuscular Septum, New England J Med. 209 74 1933.

Fowler, S. B.: Mobilization of Metacarpophalangeal Joint Arthroplasty and Capsulotomy J Bone & Joint Surg 29 193 1947

Hatt, R. N., and Lamphier, T A.: Triple Hemisection A Simplified Procedure for Lengthening the Achilles Tendon, New England J Med. 236 166 1947

Hughes, Robert E: Knee-Flexion Deformity Following Poliomyelitis. Its Correction by Operative Procedures, J Bone & Joint Surg 17: 627 1935

Irwin C. E.: Subtrochanteric Osteotomy in Poliomyelitis, J A. M. A. 133 231, 194

Irwin, C. E. The Deforming Influence of the Iliotibial Band Unpublished data.

Milch, H.: Rotation Osteotomy of the Ulna for Pronation Contracture of the Forearm, J Bone & Joint Surg 25 142, 1943

Milch H. Osteotomy of the Long Bones, Springfield Ill., 1947 Charles C Thomas.

Mitchell, Jos. I. The Residual Paralysis and Deformity of Anterior Poliomyelitis, J Bone & Joint Surg 7: 619 1925.

Moore, J R. Osteotomy-Osteoclasis A Method for Correcting Long Bone Deformities, J Bone & Joint Surg 29 119 1947

O'Donoghue, D H.: Controlled Rotation Osteotomy of the Tibia, South. M. J 33 1145, 1940

Page, C. Max An Operation for the Relief of Flexion-Contracture in the Forearm, J Bone & Joint Surg 5: 233, 1923

Pemberton Ralph, and Osgood Robert B.: The Medical and Orthopedic Management of Chronic Arthritis New York, 1934 The Macmillan Co.

Putti, V Popliteal Capsulotomy in the Treatment of Flexor Retractions of the Knee, Chir d. org di movimento. 5 11, 1921.

Sherman, Harry M.: The Operative Treatment of Pes Cavus, Am. J Orthop. Surg 2. 374, 1904-5.

Smith, S. Alwyn The Operative Treatment of Knee Flexion in Poliomyelitis, Brit. M. J 2 1092, 1924.

Soutter Robert A New Operation for Hip Contractures in Poliomyelitis, Boston M. & S. J 170 380, 1914.

Speed, J S. End Results in Transference of the Crest of the Ilium for Flexion Contracture of the Hip J Bone & Joint Surg 10 202, 1928.

Steindler Arthur A Textbook of Operative Orthopedics, New York, 1925 D Appleton & Co., p. 42.

Thompson, T C. Quadricepsplasty to Improve Knee Function, J Bone & Joint Surg 26 366, 1944.

Thompson, V P The Telescoping V Osteotomy General Method for Correcting Angular and Rotational Disalignments, Arch. Surg 46: 772 1943.

White, J W Torsion of the Achilles Tendon; Its Surgical Significance, Arch. Surg 46 784, 1943.

White, J W., and Stubbins, S. G Carpectomy for Intractable Flexion Deformities of the Wrist, J Bone & Joint Surg 26 131, 1944.

Wilson, P D Capsulectomy for the Relief of Flexion Contractures of the Elbow Following Fracture J Bone & Joint Surg 26 71 1944.

Wilson, P D: Posterior Capsuloplasty in Certain Flexion Contractures of the Knee, J Bone & Joint Surg 11 40, 1929

Yount, C. C. The Role of the Tensor Fasciae Femoris in Certain Deformities of the Lower Extremities, J Bone & Joint Surg 8 171, 1926.

CHAPTER XVII
ARTHROPLASTY

Arthroplasty is the reconstruction, not merely of the osseous structures, but of all the component parts of an articulation, for the purpose of restoring motion to the joint and function to the muscles, ligaments, tendons, and other soft tissues. The operation itself is only the first step in the re-establishment of function a carefully planned after treatment to re-educate the atrophic muscles is imperative

Arthroplasty had its inception in the resection of ankylosed joints and attempts to produce extra articular pseudoarthroses. Barton, Rodgers, Textor Esmarch Verneuil and Ollier are names connected with early efforts to restore motion in ankylosed joints. The first arthroplasty performed ac cording to present conceptions of technic was reported by Helferich, in 1893, the operation consisted of resection of an ankylosed temporomandibular joint and suture of a pedunculated flap of muscle and fascia between the articular surfaces. Thereafter a long period of experimentation followed wherein various types of heterogenous and autogenous materials were utilized for interposition. Murphy, in 1902 introduced and popularized arthroplasty in this country He perfected the pedunculated flap method of interposing fascia and fat between the articular surfaces of joints, and subsequently described procedures for the temporomandibular elbow, shoulder wrist, knee, and hip joints. In 1906 Lexer advocated the interposition of autogenous membranes such as fascia lata and reported the advantages of this method over the use of foreign materials as metal, ivory, or celluloid plates.

The development of arthroplasty to its present efficiency has been made possible by the perfection of technics following investigations of the causes of success and failure of the operation in large series of cases. Early reports were submitted by Putti and Payr in Europe and by Baer Henderson MacAusland, and Campbell in this country Contemporary reports are now available covering Smith Petersen s experience with the evolution of the mold arthroplasty

The restoration of a joint with normal function and efficiency cannot be expected. The joint is restored by functional adaptation, according to physiologic principles Obviously the problem is more difficult in the lower extrem ity than in the upper in the former not only must motion be restored but the joint must withstand weight bearing Laxity or false motion is not desir able in any reconstructed joint slight laxity is compatible with function in the upper extremity though practically none is permissible in the lower The scope of the procedure and number of successful results will increase with the experience of the surgeon

Arthroplasty must not be confused with excision which is sometimes employed in ankylosis of non weight bearing joints as the elbow and wrist Excision is simply the wide resection of bone to induce pseudarthrosis, whereas arthroplasty is designed to restore function.

INDICATIONS AND CONTRAINDICATIONS FOR ARTHROPLASTY

Care must be exercised in the selection of cases for arthroplasty The operation is not advisable in every ankylosed joint. In planning the course to pursue, therefore certain factors must be taken into consideration These will be enumerated below

1. *Arthroplasty is more often indicated and better results are secured when ankylosis is induced by either acute pyogenic infection or trauma*

2 All evidence of acute infection must have subsided at least six months, and preferably twelve months, prior to operation. This is a well known surgical maxim

3 Trauma without infection except in the elbow is seldom responsible for complete ankylosis. Often however arthroplasty is indicated following trauma, for relief of pain in an incongruous joint or when motion is blocked because of comminution of the articular surfaces.

4. In the presence of multiple ankyloses as a consequence of an acute pyogenic infection, motion may be restored in a number of joints by arthroplasty The prospect of restoration of function in any one joint is much less favorable however, than when ankylosis is confined to a single articulation ankylosis in other joints obviously inhibits the cultivation of function in the reconstructed joint

5 If ankylosis is present in only one joint and the etiologic factor is tuberculosis, arthroplasty should not be undertaken. Undoubtedly excellent results might be obtained in some cases but the probability of relighting a latent tuberculous infection and the serious consequences thereof are sufficient to contraindicate the procedure

6 In those rare cases of multiple or bilateral ankylosis of the hips or knees following tuberculosis arthroplasty of one joint may be advisable the disability is so great that the risk of relighting the tuberculous infection is justifiable.

7 In progressive arthritis of a low grade inflammatory type as atrophic arthritis, arthroplasty may be attempted after the process has become quiescent or arrested. The prognosis, however is by no means so good as when ankylosis is limited to one joint and develops from other causes.

8 When ankylosis occurs with the member in the most useful position for future function, the prognosis is much more favorable than when malposition or luxation is present.

9 If the destructive process has resulted in impairment of growth from obliteration of the epiphyses or an excessive diminution in length from loss of continuity the amount of function restored will not be sufficient to warrant the procedure

10 Abnormal osseous structure as demonstrated by the roentgenogram and atrophy of the soft tissues, may be important factors in determining the indications for arthroplasty

(a) The prognosis is less favorable when the structure has been altered for one or more inches adjacent to the articular surfaces Eburnated bone extending for a considerable distance from the articulation is not a suitable soil for the production of a functioning joint This type of osseous structure which usually follows an extensive virulent osteomyelitis bears the same relation to normal bone that fibrous scar tissue bears to normal soft tissue Not

only is dense bone poor material for the reconstruction of a joint, but the danger of relighting an acute infection is grave In the knee, dense bone constitutes a positive contraindication to arthroplasty

(b) Osteoporosis or atrophy from disuse likewise interferes with the remodeling of the bones for the new articulation In the lower extremity, when the position will permit active use with weight bearing should be encouraged for six months before arthroplasty is undertaken, in order that the bony structure may approach normal as nearly as possible If malposition prevents functional use atrophy persists indefinitely the structure of the bone can be restored only by development of function and resumption of weight bearing after correction of the deformity



Fig. 719.—A Solid bony ankylosis of knee with medullary canal traversing the joint unsatisfactory for arthroplasty B Ankylosis of knee with relatively normal density of bone suitable for arthroplasty

(3) Long periods of disuse may lead to the formation of a medulla or central canal which completely traverses the joint. In this event, also sufficient bone may not be obtained to form a satisfactory joint.

(d) The degree of atrophy of the soft tissues, particularly the muscles is commensurate with the degree of bone atrophy and the duration of the ankylosis consequently restoration of function will be difficult when muscular atrophy is excessive

11 If compensatory motion may be assured by adjacent joints, arthroplasty of an ankylosed joint is seldom advisable This is true of the shoulder and ankle When the shoulder is ankylosed motion of the shoulder girdle

will compensate largely for the lack of function. If the ankle is involved, motion in the midtarsal and subastragalar joints is increased in some measure.

12. The most favorable age for arthroplasty is between eighteen and thirty years although the procedure is justifiable in many patients until the age of forty five years, or more.

13 Arthroplasty is contraindicated in children, as the epiphyses may be injured at operation and growth arrested or distorted moreover sufficient cooperation cannot be obtained to secure the best functional result.

14. The social status and occupation of the individual must be borne in mind. Arthroplasty should be employed as a selective measure, especially in the weight bearing joints Unless a durable stable joint, which will stand average daily use, is restored, a joint ankylosed in the most useful position is far more serviceable Thus, arthroplasty is contraindicated in persons who follow strenuous occupations

The technics of the operative procedures vary according to the anatomy and function of the joints. Those most amenable to treatment by arthroplasty are the hip knee elbow and jaw Fortunately ankylosis occurs most often in these joints. In the hip reconstruction of the normal contour is the most desirable procedure In the knee and elbow the reconstruction of a simple type of joint which will restore function is preferable to the reproduction of the anatomic details of the normal articulation. Artistically, conformation to the anatomic structure is desirable but from a practical standpoint, such precision may complicate the procedure and actually *diminish the prospect of* success. In the knee one large condyle of the lower extremity of the femur and one shallow concave articular surface on the tibia will produce a hinge joint which meets all the requirements of function. The principles followed in the knee are applicable to the elbow since the latter is not a weight bearing joint, however stability is a less important factor

The procedure of arthroplasty may be divided into four parts (1) the plastic adjustment of the soft structures (2) the reconstruction of the bone, (3) the interposition of material between the articular surfaces and (4) the after treatment.

Plastic Adjustment of the Soft Structures

In planning the operation the relationship of the tendons, fasciae nerves and vessels, as well as of the articular surfaces, must receive due regard. Active function will be re-established earlier if all structures are conserved. *In correcting malposition, undue tension must not be placed* upon the nerves and vessels. Contracted tendons fasciae, and the capsule must be lengthened or rearranged by plastic adjustment to permit free function without impairing stability No tissues should be stripped from the bone unnecessarily nor should any tendons be divided until the bone has been severed as often even very large tendons may be of sufficient length to allow a fair range of motion after all scar tissue has been removed.

Reconstruction of the Bone

The fusion of the bones, whether osseous or fibrous, should be severed under direct vision. In separating the articular surfaces, force should be applied reservedly as crushing of the surfaces and fracture is always a poten

tiality The amount of bone which should be removed varies in each joint, and in the same joint according to the conditions found. A sufficient quantity should be excised to permit free motion of the joint on manual traction under no circumstances, regardless of the degree of contracture, should excision be so extensive as to prevent the formation of an adequate foundation for a functional articulation For example, should all the expanded lower extremity and condyles be removed from the humerus only the shaft would articulate with the bones of the forearm and a flail pseudarthrosis would be the outcome This in reality, would be an excision rather than an arthroplasty

In multiple ankyloses, a larger amount of bone should be resected than when only one joint is fused Motion should be insured if possible, as the patient must endure several operative procedures, further the likelihood of recurrence is much greater than when ankylosis is limited to a single joint.

Interposition of Metal or Tissue

As the tendency to reunion of the articular surfaces varies in the different joints, the interposition of tissue between the ends of the bones is more necessary in some joints than in others Even though function may be restored without the interposition of tissue clinical experience has proved that ankylosis is much less likely to recur when tissue has been interposed. Also, the fact that interposed tissue has been found to induce nonunion of fractures, or pseudarthrosis indicates that material should be inserted between the joint surfaces in arthroplasty The interposed material moreover undoubtedly plays an important part in the restoration of motion and may actually function as a synovial membrane

In the past, a number of organic and inorganic substances, such as glass, celluloid, or ivory plates, and especially prepared animal membranes, as chromicized pig's bladder have been employed in the reconstruction of ankylosed joints. They are no longer in general use however, as autogenous membranes and inert metals have been found more efficient.

Vitallium.—In 1923 Smith Petersen began experimenting with molds conforming to the shape of the head of the femur in an endeavor to find a substance which would be relatively inert in the tissues and at the same time would prevent recurrence of the ankylosis In his search for a suitable material for the mold, he tried ordinary glass, Pyrex glass, Viscaloid and Bakelite. Finally in 1938 following the introduction of Vitallium by Venable and Stuck, he found in this metal a material for interposition which appeared to meet all requirements satisfactorily The mold arthroplasty with Vitallium as interposition material is now a commonly employed procedure (p 1088)

Following Smith Petersen s success with Vitallium in the hip Campbell in four arthroplasties of the knee inserted a Vitallium plate which conformed to the contour of the reconstructed condyle of the femur The results were uniformly poor as motion was inadequate for a practical degree of function. These plates were fastened with screws so as to be immobile on the femur In the light of present knowledge this would not be a proper procedure. Possibly with better designs, the use of Vitallium for interposition between articular surfaces of superficial joints, such as the knee or elbow might prove successful.

The Pedunculated Fascial Flap—The pedunculated flap is obtained by dissection of fat and fascia in the vicinity of the joint This technic is reserved

for those cases wherein the free fascia lata transplant, described below is not available as in multiple ankyloses, and in fusion between the patella and femur accompanied by free movement between the tibia and femur Otherwise this method has been practically discarded, since often the soft tissues adjacent to the joint are involved by fibrosis as a consequence of the previous inflammation and are not therefore of desirable quality Additional dissection is required near the joint, increasing the extent of surgery and the area for possible subsequent formation of blood clots and fibrosis. Further, the flap must be almost completely freed in order to cover the joint thus, the pedicle is often so small and the blood supply so impaired that the flap becomes practically a free transplant and the one advantage of nutrition to the flap is lost

Transplants of Free Fat.—Transplants of free fat obtained from the abdomen thigh or elsewhere are employed by a few surgeons, but are not universally approved.

Free Autogenous Transplants of Fascia Lata.—The majority of surgeons use the free fascia lata transplant almost exclusively A section is removed from the external aspect of the thigh as fascia in this region is most suitable for transplantation and a sheet of sufficient size to cover any area may always be obtained For arthroplasty of the fingers, the thin delicate fascia of the inner side of the thigh is preferable to the relatively thicker fascia on the outer side The primitive synovial sac should be reproduced as fully as possible The author therefore interposes two layers of fascia lata between the articular surfaces others are content with the interposition of one layer In transplanting the fascia lata is reversed the rough outer side is placed adjacent to the bone that the smooth glistening surface may form the interior of the articulation and thereby facilitate motion

A histologic study of normal fascia lata excised at operation has been made by Professor O W Hyman of the University of Tennessee Dr Hyman found that the fibers on the under surface of the fascia lata have the appearance of tendon tissue being more regular and smooth in arrangement than those on the outer layers The outer fibers although less compact are covered with loose areolar tissue and will adhere when in contact with raw surfaces of bone. Since the structure of this side of the tissue is loose revascularization takes place earlier than on the more compact surface

AFTER-TREATMENT

The after treatment must be adapted to the mechanics of the individual joints and will be described for each one separately In the majority of cases, immediately after operation the limb is immobilized in a splint and traction is applied and maintained if feasible Fixation is continued until healing of the wound is complete which usually requires ten to fourteen days. Passive motion adapted to the requirements of each joint is then induced by special apparatus under control of the patient At the same time active motion is also cultivated with the aid of apparatus. In the beginning fear of pain on motion inhibits voluntary contracture of the muscles this can be overcome however by continued practice Unusual courage and fortitude are not necessary If the after treatment is properly planned and carried out, function is restored gradually and patients do not suffer intensely On the other hand

violent or excessive exercise induces a severe reaction, which is actually injurious and incompatible with the purposes of treatment.

Supervised physical therapy should be given daily when circumstances permit, as the cultivation of active motion, unless under the control of an expert, is very difficult after disability in any joint If such special service is not available, however, function may be restored by having the patient follow carefully planned constructive exercises The development of musculature weakened from disuse must be continued long after a satisfactory range of voluntary motion has been secured Too many patients are satisfied with a moderate range of voluntary motion and fail to cooperate in the complete restoration of muscle power

Motion must not be cultivated too rapidly The best results are obtained when passive and active motion are developed synchronously If passive motion proceeds more rapidly than active motion, the atrophic muscles may fail to respond and the weakened ligaments may be elongated, bringing about an increased laxity of the joint and diminished muscular control The joint must be examined frequently for any abnormality, such as excessive tenderness pain or swelling Upon evidence of inflammation, rest should be enforced until all active symptoms subside, treatment may then be cautiously resumed. Likewise the stamina of the ligaments and musculature must be tested A decrease in muscle power without inflammation is a danger sign and demands a careful investigation usually this indicates disintegration of the bone or stretching and increased laxity of the ligaments. Roentgenograms should be made from time to time to determine the status of the osseous structure in the presence of osteoporosis, active function should be developed as rapidly as possible When joints of the lower extremity are affected, weight bearing should not be allowed until the density of the bone approaches normal. Here again physical therapy is a valuable adjunct

The patient must be examined at frequent intervals for at least one year and often for two years postoperatively the period varying of course according to the circumstances of each case and the joint involved If the range of passive motion increases faster than the muscle power after the patient begins to walk special joints should be incorporated in the brace to limit motion to the desired degree Once active movement to thirty degrees or more has been established there is no tendency to recurrence of the ankylosis the range is increased rather than decreased If only a few degrees of active motion is possible after three months of cultivation however, recurrence is probable Strenuous exercises are usually not encouraged until the elapse of one year in this matter one must be guided by the degree of muscle power range of motion and stability of the joint and the density of the bone

Brisement forcé is seldom necessary In resistant cases motion may be increased by force under anesthesia but more than 20 to 30 degrees' increase should not be attempted at any one time efforts to induce a wider range than this may lead to a severe reaction with exudation and reorganization of inflammatory products and adhesions between the joint surfaces

PARTIAL OR HEMIARTHROPLASTY

When ankylosis follows a fracture involving the joint one articular surface may be fairly well preserved. The logical course would be to remodel

the affected articular surface, *cover this half with fascia, and leave the opposite half of the joint undisturbed* Campbell has employed such a procedure on several occasions and has usually been disappointed in the end result either ankylosis recurs or the range of motion is unsatisfactory With rare exceptions, therefore a complete arthroplasty should be carried out regardless of the state of preservation of one surface.

When a dormant infection is relighted by arthroplasty the fascia, as a rule must be removed if the infection is sufficiently severe to warrant drainage In some cases Campbell has remodeled the articular surfaces and omitted *the interposition of fascia The fact that satisfactory function was restored in a* smaller percentage of these cases points to the necessity for the use of a fascial lining in the routine arthroplasty

THE HISTOLOGIC AND PHYSIOLOGIC EVOLUTION OF A JOINT FOLLOWING FASCIAL ARTHROPLASTY

Restoration of function within a joint is made possible by a long period of systematic treatment which serves to promote an evolutionary process favorable to functional adaptation. In an endeavor to discover the nature of this evolutionary process and the ultimate status of these joints *histologically* and physiologically, investigations have been made along several lines, as follows

1 Animal experiments.

2. *Studies of clinical or functional results*

3 Roentgenographic and microscopic studies of joints wherein 'spontaneous arthroplasties' have occurred after destructive processes and un united fractures.

4. Reviews of successive roentgenograms of joints in which function has been restored by arthroplasty

5 Biopsies and autopsies of joints in which function has been restored by arthroplasty

Animal Experiments.—Animal experiments are of only slight value in the study of the problems of arthroplasty In the first place, animals with analogous pathology i e joints wherein ankylosis has occurred, are obtained with difficulty and further intelligent cooperation essential to the development of a functional joint is impossible

Murphy resected joints in dogs and interposed fat and fascia between the articular surfaces He concluded that the fat undergoes *certain changes* conducive to the formation of bursae or hygromata. Neff reports one successful arthroplasty in a dog wherein he used free transplants from the aponeurosis of the rectus muscle a new capsule formed and two bursal sacs developed. Phemister and Miller experimented with three series of dogs in one series, free transplants of fascia were interposed in another pedicle flaps of fat and fascia and in the third no material was interposed In all the results were identical being a fibrous ankylosis the interposed tissue was absorbed at points of greatest pressure

These facts are of importance only in that they prove that little practical information can be gained by animal experiments.

Clinical or Functional Results.—After restoration of function, the external contour of the joint is changed For example the kneee, the patella

and lateral sulci may not be visible the joint being cylindrical in shape. Active motion usually is commensurate with passive motion in some cases, however, depending upon the quality of the musculature and the voluntary efforts of the patient during after treatment, passive motion exceeds active motion. Also, muscle power varies in different joints after arthroplasty To illustrate in the elbow the triceps may be weak and extension accomplished largely by gravity in the knee, full extension against gravity may be impossible and in the hip, flexion to the full range may not be attained In many cases there is slight motion in an abnormal direction, as lateral motion in the knee yet not a sufficient amount to impair function. In the nonweight-bearing joints restoration of normal motion is not unusual, whereas in the weight bearing joints the normal range is rarely secured or desired In the lower extremity, 60 per cent of normal motion gives the most satisfactory weight bearing joint one which is durable and efficient beyond this point, the muscle power often is inadequate and the stability of the joint impaired. Generally, crepitus of more or less degree is elicited on motion At best, the durability and efficiency of the joint does not equal that of a normal joint

Spontaneous Arthroplasties — Spontaneous arthroplasty," or the reconstruction of a joint by nature after its complete destruction by a pathologic process, is often observed Osseous or fibrous fusion does not always take place, even after complete destruction of the articular surfaces A new joint may be formed by functional adaptation probably developing from a slight movement which gradually increases as the acute symptoms subside The status of such a joint is best demonstrated by the following case

Case Report.—Mrs. R., aged thirty years, had had an acute pyogenic infection of the right hip joint three years previously Subsidence of the acute symptoms was followed by severe pain, disability and deformity necessitating the use of crutches.

On examination, the patient was found to have a 150-degree flexion contracture of the hip. Approximately 30 degrees of motion were present in all directions. Following surgical correction of the deformity a practical range of motion was secured and weight bearing instituted. In the roentgenogram, the head of the femur and the acetabulum appeared slightly smaller than normal and the joint space diminished to much less than normal. Other than the osseous reaction of proliferation and condensation, suggestive of a previous pyogenic infection, the joint resembled one in which an arthroplasty had been performed.

This case demonstrates clearly how after extensive destruction a useful joint may be produced by a natural process. Since the joint was not entered, the evolutionary changes incident to functional adaptation could not be directly observed

In other patients with similar spontaneous arthroplasties microscopic examinations of specimens removed from the acetabulum and from the head of the femur demonstrated a superficial layer of dense fibrous connective tissue above a layer of fibrocartilage which in turn was supported by normal spongy bone. The fibrocartilage presented definite degenerative changes

Examinations were also made of ununited fractures with a typical pseudo-arthrosis. At operation the false joint with the capsule was completely excised and examined by the pathologist. Each fragment of bone was covered by a white translucent layer which appeared to be flat smooth cartilage There was a definite capsule with joint fluid On microscopic study a superficial layer of dense fibrous tissue was seen merging into a layer of atypical cartilage which might have been described as metaplastic The fibrous tissue



Fig. 720.—*A*, Spontaneous arthroplasty of the hip joint three years after acute pyogenic arthritis. A new joint has been reconstructed by a natural evolutionary process. *B*, Roentgenogram of hip five years after arthroplasty. Excellent joint space. The bone beneath articular surfaces of head of femur and ilium is condensed; the bone trabeculae are also rearranged by functional adaptation, following the new lines of stress.

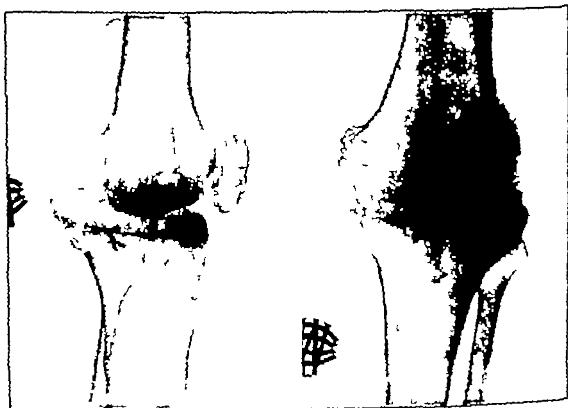


Fig. 721.—One year after arthroplasty. Joint surfaces are smooth, with good contour and joint space. Note condensation of bone beneath joint surfaces, and rearrangement of bony trabeculae. This is optimum roentgenographic appearance. Opposite extreme illustrated in Fig. 722.



Fig 13.—*A* Roentgenogram of hip six weeks after arthroplasty demonstrating satisfactory mechanical reconstruction of head and neck of femur but suspicious sequestration of head, evidently induced by disturbance of circulation at operation. *B* Definite sequestration of head of femur *C* Extrusion of sequestrum with collapse of joint and poor mechanical result.

appeared homogeneous, although there was no definite cartilage matrix. The true cartilage cells were more prevalent nearer the superficial fibrous layer Dense bone was found beneath the cartilage

The status of a joint reconstructed by nature after a pathologic process or trauma is not entirely analogous to the status of an ununited fracture, yet is similar in that in both, movement with friction between two osseous surfaces is present. In the joint there is organized function with muscles so placed as to permit voluntary active motion in an ununited fracture, the motion is entirely passive and has no relation to function.

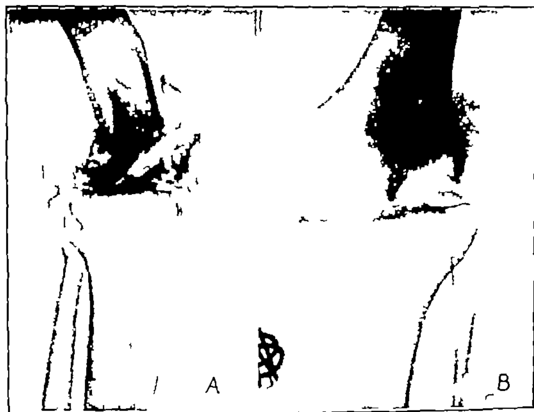


Fig. 123.—*A*. Proliferative changes about the knee joint eight years after arthroplasty indicating some involvement of the bone at time of acute process. Note fusion of patella to tibia, which apparently increased stability of the joint. Excellent functional result. *B*, Sequestration and cavity formation on lateral condyle of femur evidently from disturbance of circulation at operation. Stability and motion excellent. Usually such a complication results in instability and deformity

Roentgenograms—Valuable information may be gained by a study of successive roentgenograms after arthroplasty Campbell has reviewed over 300 films made of arthroplasties one to ten years after operation There were some variations in the findings, according to the function of the joints in question the evolutionary process as would be expected, was more apparent in the knee and hip than in the nonweight bearing joints. The joint space was less than normal especially in the lower extremities. In the majority of cases the contours of the articular surfaces were even and smooth. A small number of knee joints contained a punched out area or cavity on the lateral articular surfaces of the femur corresponding to the normal external condyle. In two or three similar though less pronounced changes were observed on the articular surfaces of the lateral condyle of the tibia In several cases the articular surfaces of the knee were compressed Successive roentgenograms

demonstrated that compression was induced by weight bearing before the structure of the bone had been sufficiently restored The relations of the articular surfaces remained unchanged, except in a small number of joints wherein the stamina of the ligaments was impaired or gross irregularities were present. In the nonweight bearing joints, irregularities were less pronounced than in the lower extremities. Gross irregularities in the head of the femur were found occasionally, and in one case the head and neck were totally absorbed. These defects may be largely obviated by disturbing the soft tissue attachments as little as possible, thus conserving the circulation, and by restricting weight bearing until the structure of the bone and musculature has been restored.

Gross irregularities after arthroplasty are not always incompatible with excellent function. For example, after removal of a loose body from the internal condyle of the femur following osteochondritis dissecans, a large cavity may remain without affecting function Many of the irregularities observed in the roentgenogram may be filled with dense fibrous tissue, the defect being more apparent than real. Unfortunately, no opportunity has been offered to prove by biopsy the status of such joints.

The structural changes, as evidenced by the roentgenogram, begin at the end of three weeks after operation with a characteristic mottling, indicating osteoporosis This increases until the effect of active use is apparent, which usually is three months. After that time the bony structure is gradually restored, as manifested by the reappearance of bone trabeculae. Because of the effect of the disease on the bone, the long period of immobilization of the joint, and the fact that function of the extremity always remains deficient to some extent, the structure of the bone, as seen in the roentgenogram never returns entirely to normal. By the end of one to three years, however the structure should approach normal. At this time a line of condensation approximately one-eighth inch in width forms just below the articular surface, with trabeculae at a right angle to the shaft. This zone of increased density is comparable to the subchondral bone plate During the ensuing year the condensed area enlarges but thereafter remains stationary this is probably an index that restoration has been accomplished so far as possible. As years go by, the rearrangement of the osseous trabeculae along the new lines of stress becomes obvious. The duration of this period of development depends largely upon the cooperation and the muscular resources of the patient

Excessive bone proliferation or formations of outgrowths or osteophytes from the articular margins were present in approximately 40 per cent of the 300 cases studied. In 25 per cent there was only slight proliferation and in 35 per cent, none at all

Biopsies and Autopsies—Biopsies and autopsies of joints in which function has been restored by arthroplasty undoubtedly will give more definite information, from the histologic and physiologic standpoints regarding the final stage of the evolutionary process. One postmortem examination was made by Sudhoff two years after arthroplasty of the elbow The patient died of some disorder in no way related to the arthroplasty or to the infection which had caused the ankylosis. A range of motion of from 45 to 165 degrees had been restored in the elbow On incision into the joint the articular surfaces were found to be smooth and covered with sheets of white fibrous tissue 2 or 3 *mm* in thickness. The interposed fascia could not be recognized. At points of great

est pressure there were blue-white areas resembling cartilaginous tissue. The joint space in the anterior portion was interrupted by a septum which formed a bursal cavity. Microscopically the capsule consisted of thick connective tissue with only a few cells; the bursal lining contained no endothelial cells, although a profusion of large cells were found here and there lining the wall. The articular fibrous tissue was poor in cells and blood vessels and contained scattered connective tissue cells and nests of hyaline cartilage. The cartilage cells appeared to have had their origin in the bordering marrow and the periosteum. At intervals, the connective tissue fibers extended from the marrow interstices into the new articular surfaces.



Fig. 724.—Twenty two years after arthroplasty: sclerotic and degenerative changes are advanced. The hip, however, still has excellent function with 90 degrees active flexion, good stability and is not painful. Usually these changes are associated with a decrease in function.

Baer, who interposed a prepared chromicized pig bladder between the articular surfaces, had occasion to open four joints after arthroplasty. His findings are quoted: "In the joints the membrane had been absorbed but a space following the outlines of the joints persisted in each case. The lining of the cavity was perfectly smooth. The microscopic sections made from the walls of these newly formed joints were as follows: The chromicized bladder had been invaded by round-cell infiltration from the side next to the denuded bone. The round cells permeated the membrane which at first became quite cellular in character. These cells finally became diminished in number and the tissue adherent to the bone was changed into a fibrous mass. The cells toward the joint

side became flattened out, but there was no distinct endothelial lining to the joint. The fibrous tissue on the adjacent bones showed no tendency to coalesce. A very noticeable feature was the entire absence of giant cells which one generally sees in the tissue surrounding any foreign body From these findings we would conclude that the membrane is transformed into a fibrous tissue which covers the denuded bone and that a joint-like space is formed with fibrous walls similar in all respects to the walls of a cavity encysting a foreign body '

MacAusland observed the following conditions at secondary operations performed after arthroplasty of the elbow 'The bone ends are smooth and covered with a firm fibrous tissue they fit snugly yet move with a firm resistance The joint space is a sac, sometimes multilocular, and contains an apparently normal joint fluid. '

Campbell has operated upon a number of patients in whom ankylosis has recurred after arthroplasty In some cases a few degrees of motion were present. A fibrous or osseous ankylosis was found the interposed tissue and the remains of the remodeled articular surfaces having been obliterated As a consequence no additional information could be gained

Six joints, wherein a practicable range of motion with function had been secured, have been opened at periods of twelve to eighteen months following arthroplasty The indication for operation in each case was a mechanical defect, such as instability Five of the operations were on the knee and one was on the hip The findings in these six joints may be summarized as follows

The skin and superficial and deep fasciae were normal In those joints opened at the end of one year the capsule was thicker than normal the thickness was increasingly less in joints opened at later periods, but was always greater than normal The joint cavity was smaller varying from one-third to one-half that of a normal joint. In two cases, fibrous bands traversed the joint in others no adhesions were present In two there was evidence of separate bursae or hygromata A joint fluid, which probably arose from connective tissue spaces in the articular surfaces, was present in five cases. The composition of the fluid was not analyzed Degenerative areas were apparent in two cases. In those observed at the end of one year the joint cavity was invested by a dense fibrous membrane which closely resembled the transplanted fascia lata in those opened after the elapse of one year the articular surfaces were of an apparently fibrocartilaginous nature the status varying according to the degree of function of the joint. In one case, wherein function was so slightly impaired that the indications for a second operation were questionable, the articular surfaces were smooth In the remainder the surfaces were rougher than normal even containing irregularities, such as furrows pits, and small eminences these however did not prevent function

The tissue structure of a joint restored by arthroplasty as *demonstrated* by microscopic examination is almost identical to that of a joint in which a spontaneous arthroplasty has occurred following a pathologic process, or a pseudoarthrosis. In these conditions there are three more or less well defined strata namely from within outward, a dense fibrous layer a stratum of atypical cartilage and the supporting bone The superficial fibrous layer is approximately from 50 to 100 microns in thickness the osseous layer is of course, continuous with the bones which comprise the articulation The *articular surfaces* apparently arise from two sources the exposed marrow spaces and the fascial transplant if the latter remains viable otherwise from the marrow alone As cartilage cells have been demonstrated in the deeper layers of the synovium and

capsule it is possible that the articular surfaces could be derived from that source The fibrocartilage, however, so evidently originates in the connective tissue of the marrow that at least a large portion of the articular surface is believed to be from this source. The strata of the superficial fibrous layer and the fibrocartilage apparently become better defined as function in the reconstructed joint is restored, the evolution of the process being influenced more by the functional adaptation of the joint than by the passage of time. The strata were best defined in three cases, wherein twelve, sixteen, and eighteen months respectively, had elapsed after arthroplasty

The superficial fibrous layer was composed of closely packed fibers which ran parallel to the articular surface and contained numerous cells with flattened nuclei This layer was continuous with the capsule. Evidence of an endothelial investment of the capsule was observed in only one case definite villi with several layers of cells could be demonstrated. This, however, may have been the remains of the former synovial membrane

The stratum of atypical cartilage beneath the superficial fibrous layer was regarded as metaplastic. In one case typical cartilage cells, in groups of two or more daughter cells were observed just beneath the fibrous layer near the surface the other portion of this layer was composed of many undeveloped cartilage cells and connective tissue fibers. No true cartilage matrix could be demonstrated, but the fibrous tissue was more homogeneous in texture, taking a little of the basic stain, and thus resembling cartilage If we assume that the first layer described was an attempt at formation of perichondrium, the remainder of the histologic picture was directly opposite to that seen in the normal investing articular cartilage i e., the daughter cells were nearer the surface after arthroplasty under normal circumstances, they are in the deeper layers nearer the bone. (This however, may be viewed in the light of nature's evolutionary process of repair which, by functional use, will in time produce a normal arrangement of adult cartilage.)

The osseous layer was continuous with the remainder of the bone which entered into the formation of the articulation the roentgenogram clearly demonstrating the structural restoration by functional adaptation.

From the presence of this dense fibrous investment in ' spontaneous arthroplasties and pseudarthrosis, in which no tissue has been interposed, the role of the fascia lata may be questioned. Whether this fascia lata lives and acts as a permanent investment membrane, is absorbed and a new stratum of fibrous tissue developed, or the fascia itself acts as a scaffold or not framework and is gradually replaced or as Baer suggests, is encysted as a foreign body is a question to be solved by the physiologist and histologist. Practical experience has proved that the fascia lata does possess a definite action conducive to the development of a joint. The fascia lata may possibly remain viable, being in close approximation to the raw osseous surface of cavernous bone and surrounding soft structures, from which revascularisation may readily take place. It is doubtful whether an inert substance would withstand the strain of early function routinely required. The fascia, however like other tissues, is altered by function in the course of time.

Conclusions—After arthroplasty a joint is developed in which function is restored to a practical degree There is a definite joint cavity containing a lubricating fluid. This cavity including the articular surface, is invested by a stratum of fibrous tissue which will, after the elapse of years be supplanted through functional adaptation by a permanent investment of fibrocartilage. The

typical hyaline cartilage of a normal joint, however is seldom, if ever, restored The structure of the bone conforms to the lines of stress produced by function of the new joint, as illustrated by the roentgenogram

SURGICAL TECHNICS

Arthroplasty is now out of the realm of experimental surgery and may be considered a routine and practical measure Although authors differ as to the details of approach and procedure, they agree upon the essential principles of the operation.

THE ANKLE

Arthroplasty of the ankle is never indicated, even though the ankle, the tarsal, and the tarsometatarsal joints are ankylosed After mobilization, there is grave danger of a painful joint with increasing disability, necessitating a subsequent operation to re-establish fusion. A stiff ankle in a good weight bearing position is quite satisfactory for function. If the ankylosed ankle is in a poor position, the procedure described on p 1022 is applicable.

THE KNEE

Restoration of function by arthroplasty and subsequent treatment is a more intricate problem in the knee than elsewhere. This is explained by the fact that the knee is the most complex articulation of the body stability is dependent upon ligamentous support on all four sides externally as well as within the joint, upon the muscles which pass across the joint, and upon the contours of the articular surfaces.

Indications and Contraindications for Arthroplasty of the Knee.—Aside from the indications and contraindications for arthroplasty described for joints in general in the selection and execution of the procedure for the knee one should also be guided by the following considerations

1 The position of the knee is important. Ankylosis in full extension or not more than 150 degrees flexion is most favorable for arthroplasty Flexion contracture of over 100 degrees renders the result more uncertain.

2. Shortening of more than three inches from destruction of bone or lack of growth is a contraindication to mobilization the further excision of bone which would be necessary and the slight improvement in function gained would not justify the operation

3 In large obese patients, especially women the musculature and ligaments are always deficient. In these individuals, not only should the ligaments be conserved but as little bone as possible should be removed in forming the joint space otherwise, a loose flail joint is likely to be the outcome.

In remodeling the knee joint no single technic is applicable to all cases. The procedure must be modified according to (1) the distribution of the ankylosis i.e., (a) panankylosis, or complete bony fusion of the patella femur and tibia (b) tibiofemoral fusion with freely movable patella and (c) fusion of the patella and femur associated with an apparently normal tibiofemoral articulation and (2) position i.e (a) extension or slight flexion and (b) acute flexion with or without external rotation

The cruciate ligaments, a major stabilizing element of the knee joint are either destroyed by the process which produces the ankylosis or must be sacrificed in remodeling the joint for arthroplasty Exact coaptation of the sur

faces of the articulation cannot, therefore be maintained. Experience has shown that with prolonged usage, all reconstructed joints follow the laws of functional adaptation, tending to form the simplest type of articulations. The technic described by Haas is predicated upon the expectation that such a functional adaptation will take place He transforms the proximal element of the joint into a transverse wedge and observes that the end of the bone eventually attains a rounded form and structure, corresponding to the demands of function. Rather than impose an extra burden upon the reparative and adaptive processes, a rounded or convex surface we feel, should be created by surgery

In contrast to the technics of Putti and MacAusland, we make no attempt to reconstruct the normal osseous contours of the joint namely the two femoral condyles with the intervening intercondylar notch and the tibial spine with concavities in the articular surface of the tibia for reception of the femoral condyles Instead only two large condyles are formed one convex femoral condyle and a corresponding single concavity in the tibial condyles.

Pan Ankylosis in Extension or Slight Flexion

Ankylosis of this type and in this position is observed most often. In Campbell s early arthroplasties, the quadriceps tendon was always lengthened when the knee was ankylosed in extension. Experience has shown that, as a rule, this is not only unnecessary but inadvisable. The following surgical procedure has been found most suitable

Technic (Campbell) —The incision is begun four to six inches above the knee at the inner border of the quadriceps tendon extended downward, with a slight convexity inward, parallel to the medial aspect of this tendon, and terminated just below the attachment of the patellar tendon to the tibia. The skin and superficial and deep fasciae are incised and the quadriceps tendon and vastus internus muscles separated at their junction. The quadriceps tendon is freed down to the patella and the bony union between the patella and the femur is divided with a chisel The quadriceps tendon, patella, and patellar tendon are retracted laterally and any fibrous tissue adhesions which prevent adequate exposure of the ankylosed joint are divided with a scalpel. Exposure should be accomplished as subperiosteally as possible. Ankylosis between the tibia and femur is next divided with an osteotome, with care to avoid injury to the structures posterior to the capsule. Until the tibiofemoral union is completely severed, forcible flexion should not be attempted, even though the ankylosis is fibrous, as fractures of the lower extremity of the femur are easily sustained and may be a serious complication.

The knee is then gradually flexed to give complete access to the articular surfaces of the tibia and femur and the posterior portions of the condyles of the femur are removed thus obliterating the intercondylar notch and permitting full flexion The lower extremity of the femur is now made convex from above downward and from before backward, forming one large condyle. Only an amount of bone is removed from the actual length of the femur as is essential to reach cancellous bone the larger portion of bone is taken from the posterior surface of the condyles By this means wider space will be obtained and the length of the limb will be affected only slightly if at all The upper extremity of the tibia, also is resected as little as possible in order to reach healthy spongy bone. With a wood-carver s chisel or one and one-half inch gouge, this surface is made slightly concave from before backward forming one large shallow cavity

for articulation with the one condyle of the femur After excision of the bone manual traction on the tibia should produce at least one half inch of space between the ends of the tibia and femur No attempt is made to reproduce the spine of the tibia or the intercondylar notch of the femur since there will be no cruciate ligaments, slight lateral displacement might easily occur when motion is instituted bringing the irregular surfaces together and causing mechanical damage. The broad osseous support provided by a hinge type of joint the postoperative fibrous tissue reaction and the development of muscle power compensate for the loss of the cruciate ligaments Further to prevent lateral instability the medial and lateral ligaments must be protected from injury or stretching during operation. Extreme caution must be exercised to avoid separation of the soft tissues from the bone as these provide the chief blood supply of the bone and thus protect the articular surfaces from ischemic necrosis.

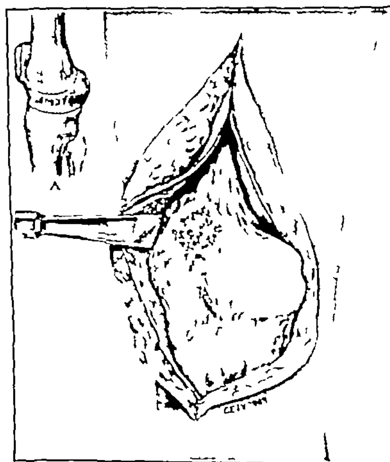


FIG. 7 5.—Arthroplasty of the knee Exposure of ankylosed joint. Quadriceps tendon freed and ankylosis between patella and femur divided. Detail indicates amount of bone resected.

The bony surfaces are next approximated and the alignment of the entire extremity is observed. If varus or valgus is present additional bone is removed from each surface until a perfectly straight hinge is formed. One should especially guard against producing valgus deformity regardless of the position of the normal limb future weight bearing must be direct and in a straight line

Attention is next directed to the patella Its posterior surface is removed leaving only a thin layer of bone consistent with tensile strength The lateral margins are trimmed for one fourth inch to allow the fibers along the edge of the tendon to fold backward onto the posterior surface All osseous surfaces

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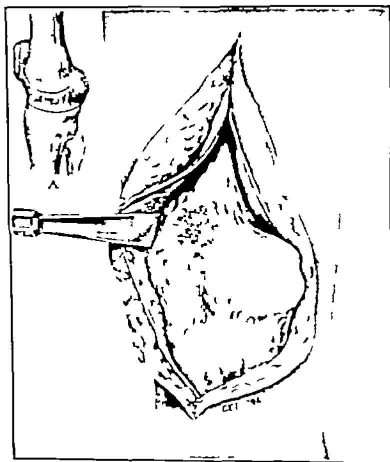


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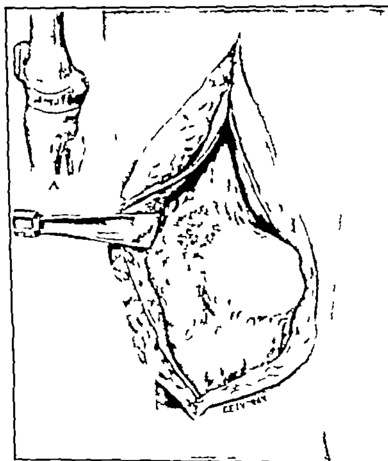


Fig. 725—Arthroplasty of the knee. Exposure of ankylosed joint. Quadriceps tendon freed and ankylosis between patella and femur divided. Detail indicates amount of bone resected.

The bony surfaces are next approximated and the alignment of the entire extremity is observed. If varus or valgus is present additional bone is removed from each surface until a perfectly straight hinge is formed. One should especially guard against producing valgus deformity regardless of the position of the normal limb future weight bearing must be direct and in a straight line

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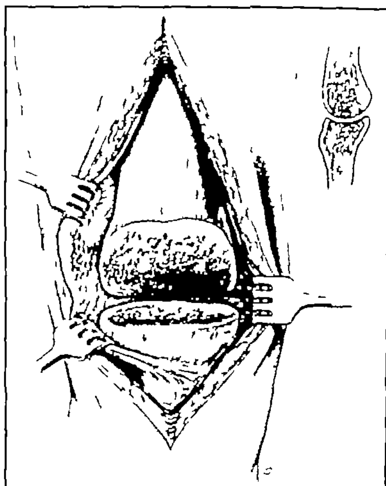


Fig. 726.—Reconstruction of articular surfaces with formation of one large convex femoral condyle and a shallow concavity in condyle of tibia. Patella remodeled, one-half its thickness removed. Detail of lateral view after remodeling.

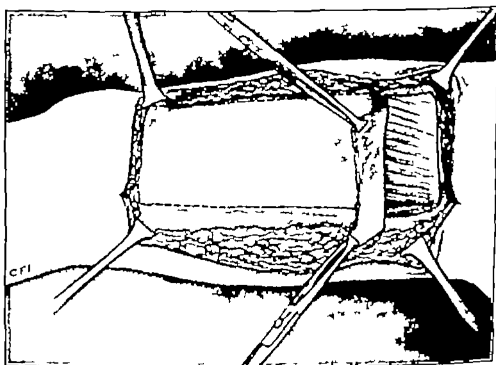


Fig. 727.—Removal of fascia lata from thigh.

are smoothed with a rasp. All recesses are carefully searched and every particle of loose bone is removed. Just below the patella and on the posterior aspect of the patellar tendon will be found a mass of fat and perhaps remains of synovial membrane; this is severed at its juncture with the tibia and dissected from below upward, forming a flap with a broad pedicle. The flap is stitched to the margin of the tendinous fibers, thus investing the posterior surface of the patella. If the fatty tissue is deficient, the posterior surface of the patella is covered by a free transplant of fascia lata. This is an important step, as restoration of mobility to the patella is a most difficult problem and, in the event of recurrence of ankylosis, adhesions begin between the patella and femur.

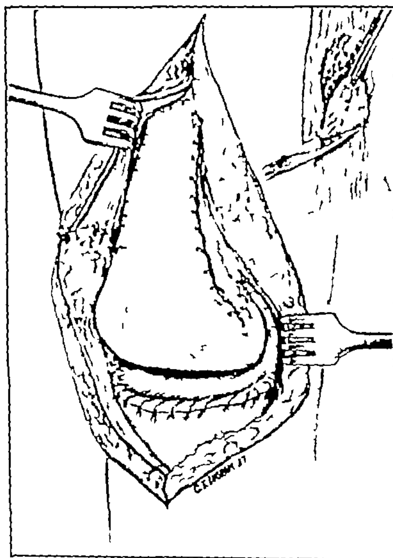


Fig. 728.—New joint lined with fascia lata, forming a double layer between tibia and femur. Fascia sutured deeply in posterior compartment of joint. Detail shows manner of covering patella with pedunculated flap of fat and fascia.

The contour of the new joint has now been reconstructed and prepared for interposition of the membrane. As the former infection may have produced fibrosis in the soft tissues about the operative area and in order to avoid excessive surgery to the one member, the transplant is best obtained from the opposite thigh. To expedite the procedure assistants should remove the transplant while the operation on the knee is in progress. A long incision is made on the outer aspect of the opposite thigh and a strip of fascia lata four or five inches in

width and eight or ten inches in length is excised. In applying the transplant, the rough outer surface should always be placed in contact with the raw osseous surfaces. The transplant is therefore folded with its smooth surface inward, two-thirds of its length forming the superior portion. The folded edge is anchored to the posterior capsule of the knee joint by three stitches of chromic

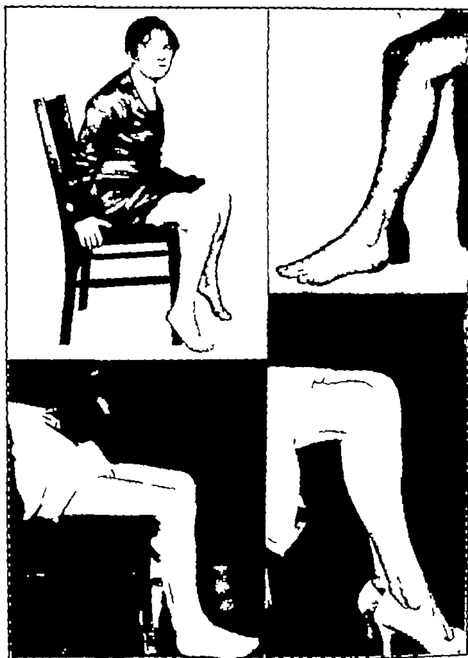


Fig. 739.—Range of flexion in 4 cases following arthroplasty of the knee. All patients had complete active extension.

catgut, one on each side and one in the center. The upper portion of the transplant is then placed over the distal four or five inches of the anterior aspect of the femur and the lower fold is brought forward over the new articular surface of the tibia to the anterior aspect. With a continuous suture of chromic catgut all free edges are stitched to the periosteum and soft structures, well over the margins of the joint. If the soft tissues about the joint are deficient, the fascia

must be held in place by sutures passed through holes drilled in the bone Should the bone be soft the holes may readily be made with a Lewin clamp Thus, not only are two layers of fascia lata interposed between the joint surfaces, but one layer is interposed between the quadriceps tendon and the tissues on the anterior surface of the femur The pedicle flap forms an additional layer between the patella and femur The joint capsule fascia and skin are sutured in the routine manner chromic catgut being used for the deep structures

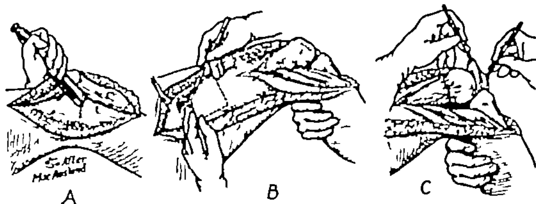


Fig. 730 —Arthroplasty of the knee (technic Putti) *A*, Joint exposed by anterolateral incision, *tibial tubercle detached. B Joint surfaces remodeled to conform to anatomic contour C*, New articular surfaces covered with fascia lata. (Redrawn from MacAusland, W R., and MacAusland, A. R.: The Mobilization of Ankylosed Joints by Arthoplasty Philadelphia 1929 Lea & Febiger)

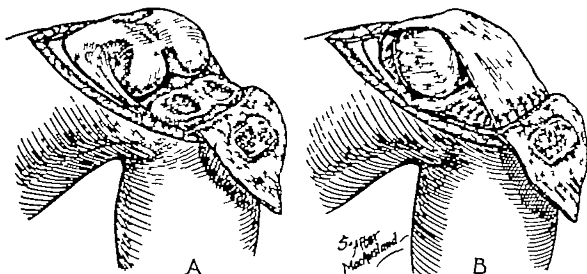


Fig. 731 —Arthroplasty of the knee (technic MacAusland) *A* Joint exposed by inverted U incision; remodeled along anatomic lines. *B* Method of lining joint with fascia. (Redrawn from MacAusland, W R. and MacAusland A. R. The Mobilization of Ankylosed Joints by Arthroplasty Philadelphia, 1929 Lea & Febiger)

After Treatment.—Immediately after operation moderate traction is applied and the limb is immobilized in a special arthroplasty splint (p 75) The splint is locked in the extended position and no motion is permitted in the joint until the wound has entirely healed Active contractures of the quadriceps muscle, however are encouraged after the fifth day Ten days postoperatively motion may be instituted under the control of the patient the splint being retained meanwhile. Active and passive motion should be increased synchronously

In obese patients, or in the presence of a long-standing ankylosis with commensurately weakened and atrophied muscles, the following routine is carried out to prevent undue laxity: The extremity is placed in a single spica

cast which extends from the toes to a point above the iliac crests, and a large window is removed from the cast anteriorly to allow for postoperative swelling Two to three weeks later a second cast is applied from the groin to the toes, in which hinge joints are incorporated at the knee.

At the end of thirty days motion in the knee should not exceed 30 degrees, and at the end of sixty days, not more than 40 degrees. If motion is increased too rapidly, the atrophic ligaments may become overstretched. Further, since the bones are osteoporotic, the articular surfaces may be compressed, increasing the joint space and causing irregularity thus adding to the danger of producing an unstable joint. The reeducation of both the extensor and flexor groups of muscles is important. Complete extension is essential. Flexion of 120 to 100 degrees gives the best function and a member which can be used for practically all purposes.

If the joint is stable at the end of six weeks, the splint is removed and walking allowed in a brace with an adjustable joint at the knee to permit gradual increase of motion (p 38) If osteoporosis is excessive, a portion of the weight should be borne by a Thomas ring added to the brace Full weight-bearing should not be allowed until the structure of the bone approaches normal and *a fair degree of power has been developed in the quadriceps muscle*. When the *patient begins to walk, the knee should be diligently exercised until the maximum* power has been restored.

Technic (Putti) —A U-shaped incision is made, extending from the lateral condyle of the femur downward, across the distal portion of the patellar tendon, and upward to the opposite femoral condyle. (When scars are present following previous operations, making the U incision inadvisable, Putti employs a medial curved incision and severs the tibial tubercle.) A segment of bone 3 by 4 cm., including the tibial tubercle and the insertion of the patellar tendon is removed with a chisel the ankylosis between the patella and femur is broken up and the joint exposed. Beginning on the outer side and working inward with special curved chisels, the femur and tibia are *remodeled, the transverse* diameter of the condyles being preserved, while the sagittal dimension is decreased. Sufficient bone is resected to form a joint space of 1 cm. when traction is applied to the leg The spine of the tibia and the intercondylar notch of the femur are then reconstructed, that the articular contours may be as nearly normal as possible. After smoothing the surfaces with a file, a free transplant of fascia lata is sutured over the ends of both bones. The tibial tubercle is replaced and fixed with a metal nail.

Technic (MacAusland) —The skin is incised longitudinally in the midline and the deep structures are divided by an inverted V-shaped incision with its apex *three inches proximal to the patella This V-shaped flap*, consisting of the capsule, periarticular structures, patella, and a portion of the quadriceps tendon, *is turned downward* The joint surfaces are remodeled to conform as closely as possible to the normal contour two femoral condyles, an intercondylar notch, and concavities in the tibial condyles being created. A cup-shaped space is excavated on the anterior surface of the femur to articulate with the patella. In covering the articular surfaces of the femur and tibia with fascia, the flap is first sutured over the tibia then to the posterior capsule. The flap is next carried upward over the femur and tied securely in place with a purse-string suture The remaining portion of the fascia should be of adequate length to be reflected distally to the anterior margin of the tibial condyles.

Technic (Albee) —Albee employs a technic wherein the joint is exposed by a U shaped incision and the tibial tubercle is detached In remodeling the joint surfaces, the femoral condyles are reconstructed to form a 120 degree V shaped wedge with its apex distally In turn the tibial condyles are remodeled into a V shaped concavity to receive the convex surface of the femur

Albee believes that, by so remodeling the joint lateral instability can be avoided

Pan Ankylosis of the Knee in Acute Flexion

Ankylosis of the knee in flexion of not more than 120 degrees is best corrected by the operation described above If flexion exceeds 120 degrees a two-stage procedure is often advisable In the first stage, the ankylosis is broken up and the deformity corrected to an extent which will permit weight bearing

Technic.—*The posterior portions of the condyles of the tibia and femur* are exposed through a three inch incision on the posterolateral aspect of the knee (p 178) A one inch chisel is driven transversely between the posterior portion of the joint severing the fusion If necessary, further extension may be obtained by posterior capsulotomy (p 1030)

After Treatment.—*If there is difficulty in correcting the deformity* skin traction or skeletal traction may be applied until the desired degree of extension is acquired The extremity is then placed in a cast and so maintained for six weeks. Upon removal of the cast weight bearing is instituted gradually the knee being supported by a brace until the osseous and soft structures are *sufficiently normal to permit arthroplasty*

Ankylosis of the Patella and Femur

Fusion of the patella and femur in the presence of a relatively normal tibiofemoral articulation is seldom encountered. If so a patellectomy should be adequate and is preferable to arthroplasty of the patella. As a rule the articular surfaces of the femur and tibia are united to a degree which warrants a complete arthroplasty Incomplete or hemiarthroplasties are rarely satisfactory reconstruction of the entire joint offers a much better prognosis

Technic.—An anterolateral incision eight inches in length is begun at the tibial tubercle *carried across the knee joint to the lateral aspect of the* thigh, thence through the deep structures along the lateral border of the quadriceps tendon patella and patellar tendon With a scalpel, the quadriceps tendon is dissected free from the musculotendinous junction proximally to the patella. Union between the patella and femur is then severed by means of a chisel and the *raw osseous surfaces are smoothed with a file as a rule, one half* the thickness of the patella is removed in this process. Through the proximal end of the incision a broad sheet of fascia lata is dissected from the outer aspect of the thigh of the same extremity The fascia is folded double one-half of its rough surface approximating the posterior portion of the quadriceps tendon and the raw surface of the patella, and the other *half covering the apposing* area of the femur The transplant is held in place by means of interrupted stitches of No 1 chromic catgut.

After Treatment.—The measures described on p 1075 are also suitable here, although weight bearing and active use of the extremity are begun earlier

Tibiofemoral Ankylosis With Freely Movable Patella

Tibiofemoral ankylosis with a freely movable patella is also rarely observed The condition may be a sequela of acute infectious arthritis, but is more often

the result of a virulent osteomyelitis extending for a considerable distance into the shafts of the tibia and femur with direct infection of the joint. The patella will remain movable if the anterior portion of the joint has been walled off by inflammatory exudate and protected from the infection in a manner analogous to the reaction which so frequently takes place in the abdominal cavity If the osteomyelitis has been extensive, the indication for arthroplasty is most questionable Should arthroplasty be deemed advisable, however the patellar tendon is retracted laterally and the operation is carried out in the routine manner the pedicle flap to the patella being omitted.

End Results of Arthroplasty of the Knee*

One hundred and ninety four arthroplasties of the knee have been performed in this Clinic An analysis of these cases is now in progress. Forty patients have recently been observed all six or more years postoperatively Thus far the two longest follow up examinations are 26 and 22 years. Although a detailed analysis of these cases is not appropriate for this text, certain general impressions as to arthroplasties of the knee seem worth while. A comparison of the end results of arthroplastics of the knee and those of arthroplasty of the hip also furnishes some interesting analogies.

Arthroplasties of the knee have withstood the ravages of time, wear and tear far better than the fascial arthroplasties of the hip both from a functional and a roentgenologic standpoint. The hips (p 1086) usually undergo progressive degenerative changes over a period of ten or fifteen years, with proliferation of bone about the joint function decreases though not necessarily in proportion to the roentgenographic changes. By contrast, the degenerative and adaptive changes in knee joints following arthroplasty with only a few exceptions, become static five to seven years after operation During the first two or three years after operation, the joint is in a changing state and rarely attains its maximum degree of motion stability or functional capacity After the settling down of the joint surfaces ceases, a certain amount of residual incongruity and absorption is usually present. As a rule, this is within tolerable limits. Muscular control and the range of motion then improve over a period of an additional two or three years thus, the knee reaches its maximum peak of function at five to seven years after the arthroplasty and thereafter both the functional result and the roentgenographic appearance remain stationary (Figs. 733, 734) The eventual functional capacity of the knee joint is predicated upon the ability of the patient to develop muscular control until the knee will extend strongly and lock or stabilize the joint in extension. Many patients with poor function at two years have returned at six or more years after operation with an excellent result.

Following the average arthroplasty of the knee the joint has 60 to 70 degrees of motion, ordinarily associated with a grating beneath the patella which may become painful after excessive use. When the muscles are relaxed and the joint is flexed there is considerable instability When the muscles are tense particularly if the joint is in extension little instability can be detected. These patients walk very well on level ground without a perceptible limp but may have difficulty in negotiating steps in the ordinary manner Those with wider ranges of motion may by raising themselves high on the toes of the normal side go up steps with only a slight variance from normal gait.

The ability of these joints to withstand the test of time is demonstrated by the two longest follow ups in the recent series. One patient, 26 years after

* J S. Speed and P C. Trout.

Fig. 732.—Roentgenogram of knee one year after arthroplasty. Excellent joint space with smooth articular surfaces.



Fig. 733.—Same as Fig. 732. Four years after arthroplasty, period of readjustment and functional adaptation is complete.

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Fig. 733.—Same as Fig. 732. Four years after arthroplasty; period of readjustment and functional adaptation is complete.



Fig. 734.—Same as Fig. 732. Twenty-two years after arthroplasty roentgenographic appearance of knee differs but little from that observed four years after operation. Patient has a stable joint with 70 degrees' motion and is able to walk six or seven miles over rough ground without discomfort.



Fig. 735.—Same patient as Fig. 733 A 26 years after arthroplasty. Roentgenographic appearance and functional result have remained static for 20 years. Despite proliferative changes and poor roentgenographic appearance, with fusion of patella to tibia, patient has 60 degrees' motion and a painless, stable knee. She has earned her living in a sedentary occupation without any difficulty

arthroplasty works at a sedentary occupation has 65 degrees of motion and no pain The other 22 years after arthroplasty is a Girl Scout Master and is able to walk six or seven miles across rough ground without discomfort She has 180 to 110 degrees of motion in the knee

The recent analysis of long term follow up cases has convincingly shown that a satisfactory knee joint can be reconstructed by arthroplasty that this joint will withstand average daily use remarkably well for an indefinite time

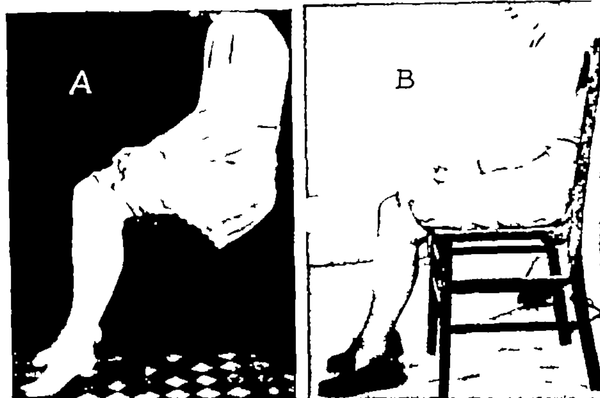


Fig. 736.—Same as Fig 735. *A* Eight years after arthroplasty *B* Twenty-six years after arthroplasty

THE HIP

The hip being a ball and socket joint does not depend so much upon ligamentous and muscular support for stability as do other joints. Mechanically therefore the hip is ideal for arthroplasty clinically the outcome is less satisfactory than in the knee In many cases the head of the femur either contains numerous cystic areas or is eburnated and in order to reach cancellous tissue suitable for arthroplasty the bone must be excised extensively This results in a certain amount of instability and an associated limp

Bilateral ankylosis is observed far more often in the hip than in other joints. From an analysis of Campbell s records the incidence of bilateral ankylosis of the hip is appreciably higher in men than in women whereas in unilateral ankylosis the reverse is true The hip is also more frequently involved in polyarticular ankylosis than is any other joint.

Campbell s technic for arthroplasty of the hip is a modification of the original Murphy operation Murphy approached the joint through a lateral U incision and in some cases made a second incision downward at the center of the U the so-called goblet incision. He removed and reattached the greater trochanter and further utilized a long pedicle flap interposing only one



Fig. 737.—*A*, Ankylosis of hip joint with cystic areas in head of femur unsatisfactory for fascial arthroplasty. *B*, Solid ankylosis of hip joint with formation of trabeculae across old joint line according to stresses and strains of weight bearing suitable for arthroplasty.

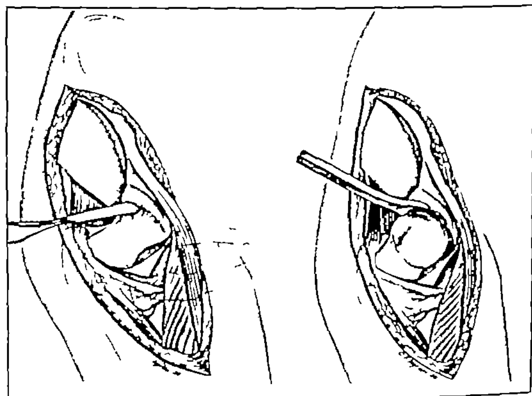


Fig. 738.—Arthroplasty of the hip. *A*, Exposure of ankylosed hip joint. Murphy gouge is first driven into ilium at right angle, to distance of one and one-half inches. *B*, Fused surfaces separated by large wood-carver's chisel. (Smith Petersen chisel is now used in preference to that shown above.)

layer of tissue in the joint Formerly Campbell employed the lateral incision but later used the anterior iliofemoral approach which is more appropriate mechanically and physiologically The plan of reconstruction is different *from that followed in arthroplasties of other joints* the head of the femur and the acetabulum are remodeled to conform as nearly as possible to their normal contours

Technic (Campbell) —The hip is exposed by a Smith Petersen incision (p 1090) The line of union between the head of the femur and the ilium is not always visible as osseous fusion may be so completely organized that the neck of the femur is structurally continuous with the ilium Beginning at a point one fourth inch above the acetabulum a large Murphy gouge is driven into the ilium at a right angle for a distance of one to one and one half inches A Smith Petersen chisel which conforms to the normal contour of the head of the femur is then inserted into this cleft and the fused surfaces are separated The hip is dislocated by *forcible adduction and external rotation* this provides an excellent view of the head and the acetabulum Should adhesions on the inferior aspect of the acetabulum interfere with dislocation they may be freed by curved scissors as the head is disengaged

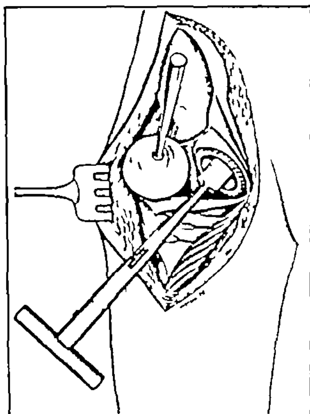


Fig. 39 —Articular surfaces of head of femur and acetabulum smoothed with special reamers

Attention is next directed to all contracted soft structures, as these must be relaxed before construction of the articular surfaces is begun Flexion contracture is released by stripping the attachments of the tensor fasciae femoris and gluteal muscles from the ilium and dividing the sartorius and rectus femoris muscles at their origins Adduction when present, is corrected by subcutaneous tenotomy of the adductor tendons Severance of the soft structure attachments of the neck should be limited so far as possible in order to conserve the blood supply to the head of the femur Following relaxation of the soft tissues the hip is *rotated externally and adducted* to an

Fig. 749.—The hip has been dislocated after osteotomy of the inferior half of the anterior inferior iliac spine and anterior acetabular wall. Both sides of the joint are now accessible for reconstruction. (From Smith-Petersen, M. N.: J. Bone & Joint Surg. 30-B: 59, 1948.)

Fig. 750.—The head of the femur and the acetabulum have been reshaped resulting in a joint with relatively congruous surfaces.

Periosteal Branch of Deep Circumflex Iliac A
Osteotomized Ant Iliac Crest
Reflected Head of Rectus M
Rectus M Sutured

Fig. 751.—The mold has been applied. It fits loosely over the femoral head and there is an ample joint space between it and the acetabulum.

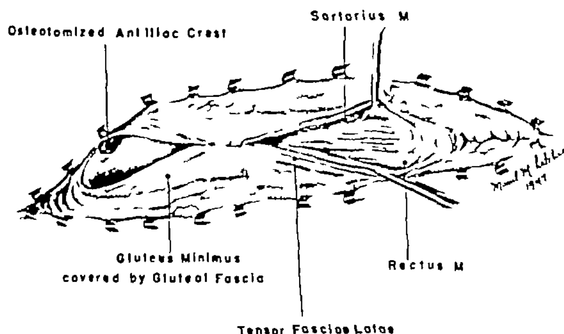


Fig. 752.—The anterior iliac crest has been osteotomized allowing suture without tension of the abdominal to the gluteal structures.

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Fig. 51.—The mold has been applied It fits loosely over the femoral head and there is an ample joint space between it and the acetabulum.

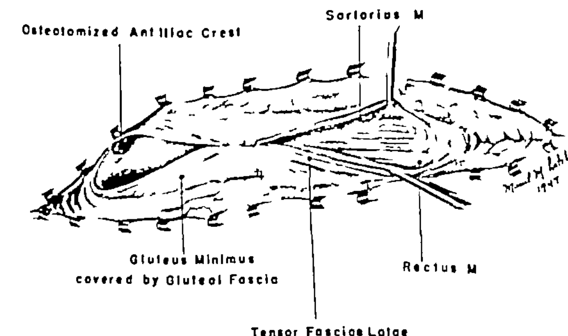


Fig. 752.—The anterior iliac crest has been osteotomized allowing suture without tension of the abdominal to the gluteal structures.

erally along the mesial border of the tensor fasciae latae. It terminates approximately 2 inches below the level of the lesser trochanter (Fig 746.)

The superficial fat and fascia are incised down to the deep fascia covering the external abdominal oblique and gluteal muscles superiorly and the sartorius and tensor fasciae latae inferiorly. Between the sartorius and the tensor fasciae latae there is a fat compartment covering the upper portion of the *rectus femoris*. *By incising the femoral fascia between the sartorius and the* tensor fasciae latae a plane of cleavage becomes apparent between the posterior surface of the sartorius and the anterior surface of the iliopsoas as it emerges from underneath Poupart's ligament. This plane of cleavage is easily developed by blunt dissection. (Fig 747.)

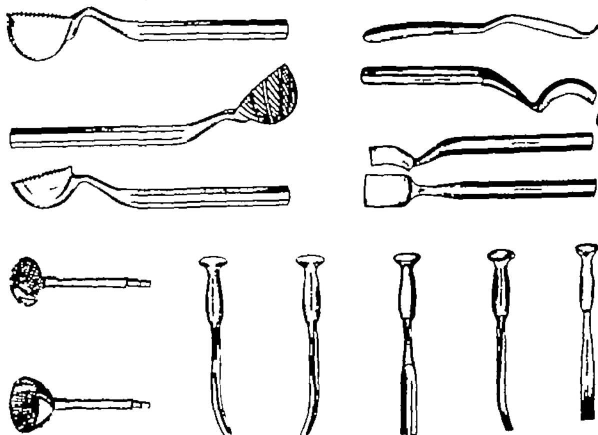


Fig. 753.—Instruments necessary for remodelling the hip joint. The reamers and gouges have the same curves; they were designed to approximate the curves of the normal femoral head. (From Smith-Petersen, M. N.: J. Bone & Joint Surg. 30-B: 59, 1948.)

The attention is now directed toward developing the superior portion of the approach. The plane of cleavage between the abdominal and gluteal fasciae is defined and an incision made through the periosteum down to bone. By periosteal reflection of the attachments of the abdominal muscles, sartorius and Poupart's ligament mesially and of the gluteus medius, tensor fasciae latae and gluteus minimus laterally the anterior third of the ilium is exposed.

In order to expose the anterior capsule of the hip joint, the deep iliac fascia is divided between the main origin and the acetabular origin of the iliacus muscle. The motor fibers from the femoral nerve to the rectus femoris

must always be exposed they are surrounded by fat and lie on the anterior surface of the iliacus muscle directly beneath the iliac fascia as it becomes confluent with the deep femoral fascia (Fig 748)

The anterior inferior iliac spine has now been exposed Attached to it we have the direct head of the rectus femoris muscle and the acetabular origin



Fig. 754.—H. F Preoperative x ray A woman of 75 with increasing limitation of activity because of a painful left hip. Note: overgrowth of bone shallow laterally displaced acetabulum. Misshapen femoral head. Loss of joint line.



Fig. 755.—H. F Postoperative x ray 6¼ years after arthroplasty Patient now 81½ years of age. Walks without a limp. Operated hip slightly more freely movable than the un operated hip. Note overgrowth of bone, lateral aspect of ilium secondary to reflection of periosteum no symptoms referable to it. Acetabulum has been slightly deepened There has been no shortening of the femoral head and neck. There is evidence of a new joint lining.

of the iliacus muscle mesially Laterally the reflected head of the rectus is concealed in the supra-articular fat compartment.

All joints have periarticular fat compartments whose function is to facilitate the gliding mechanism close to the joint. In the case of the hip joint, we

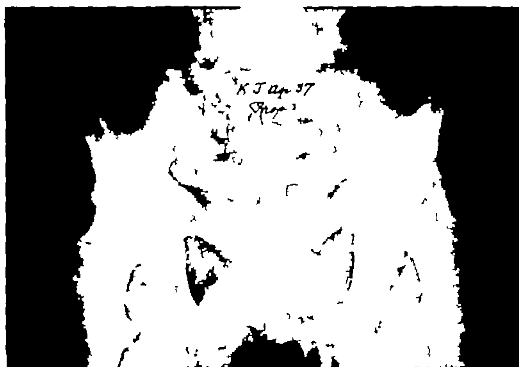


Fig. 756—K. J A young man of 37 with complete bony ankylosis of the spine and fibrous ankylosis of the hips. Preoperative film shows advanced bone atrophy accompanied by intrapelvic protrusion of the acetabula.

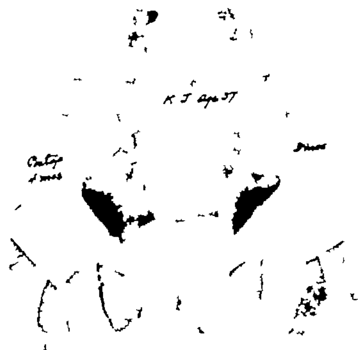


Fig. 757—K. J Postoperative film relationship of the molds to the acetabula heads.

have such fat compartments, medially, inferior to the origin of the iliacus from the iliac fossa and laterally between the superior aspect of the capsule and the inferior origin of the gluteus minimus. These are the fat compartments that we are mainly interested in as far as exposure of the hip joint is

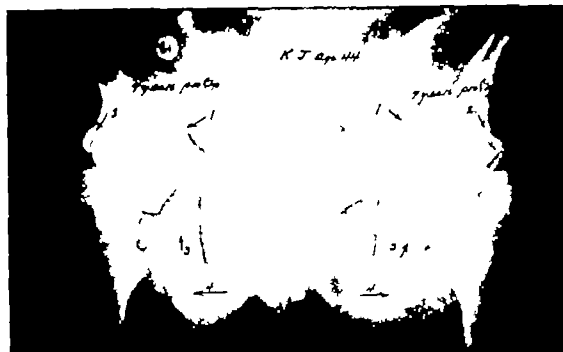


Fig. 758.—h. J 7 years postoperative, film shows an increased intrapelvic protrusion of the acetabula, overgrowth of bone gripping the molds both superiorly and inferiorly. Patient was sufficiently relieved of pain by the primary arthroplasty so that he could remain ambulatory and lead quite an active life.



Fig. 759.—K. J 2½ months post revision. Bony overgrowth has been removed allowing the molds to move freely in the acetabula.

concerned we have similar structural relationships posteriorly and inferiorly, but these are of less importance surgically

By retracting the iliopsoas mesially the anterior and inferior capsule of the hip joint is exposed (Fig 748) The rectus muscle and the acetabular origin of the iliacus muscle are divided close to the anterior inferior iliac spine and reflected laterally with the limbs of the Y ligament of Bigelow and the fibrous portion of the joint capsule

An osteotomy of the anterior inferior iliac spine and the anterior acetabular wall is now performed Attached to this bony structure are remnants of the fibrous capsule and the synovia, these are all excised with due respect for the distal attachments of the capsule since this is the point of entrance of the circulation to the head and neck By this procedure the anterior aspect of the head and neck are exposed, rendering both sides of the joint available for complete reconstruction



Fig. 752.—R. G 5 years after bilateral arthroplasty Film taken in maximum abduction. It is instructive to note that this movement takes place chiefly between the molds and the acetabula, but there is also evidence of movement of the femoral head inside the mold.

Arthroplasty of any type requires dislocation of the joint. In the case of the hip joint this step in the procedure is often very difficult. By sacrificing the inferior half of the inferior iliac spine and the anterior acetabular wall before attempting to dislocate the hip this maneuver is greatly facilitated (Figs 749 750) The extent and type of reconstruction of the joint varies

The purpose of the operation is to create a joint with approximately normal mechanics This supplies the clue to the fitting of the mold Normally joint surfaces glide over one another with a minimum amount of friction consequently the mold must be loosely fitted so as to allow the greatest possible range of motion between it and the adjacent, reshaped surfaces of the femoral head and the acetabulum (Fig 751)

Before closing the wound it is advisable to try out the function of the joint as far as range of motion and stability are concerned. This gives the surgeon information which enables him to decide upon the optimum post operative position and to guide postoperative exercises intelligently

The closure of the wound is relatively simple since the approach follows structural planes. The direct head of the rectus muscle is sutured to the reflected head if this has been preserved, if not, it is sutured to the central tendon of the gluteus minimus. By excision of the anterior superior iliac spine and crest, the abdominal muscles and fascia are sutured to the gluteal muscles and fascia without tension (Fig 752) The deep and superficial fasciae are approximated in layers.

Because of uncontrollable oozing from cancellous bone surfaces there is considerable loss of blood. Transfusions are therefore administered from the beginning of the operation in order to prevent serious shock. The approach is frequently bloodless—it is only the exceptional case that requires ligatures—diathermy stasis is all that is indicated.

Instruments*

A carpenter has his workbench with its vise. He can adjust his stock to any position necessary for good workmanship He has good tools—so good that many surgeons advocate their use in bone surgery A surgeon has no workbench and no vise in which he can adjust his stock. His instruments, therefore must be designed to overcome this difficulty they must reach places out of sight, cut away bone around the corner and polish surfaces inaccessible to the rasp or the file (Fig 753)

Gouges of various sizes with curves corresponding to the surfaces of a normal hip joint have been in use since 1925 It is thrilling to watch them disappear from sight knowing that if given the proper start they cannot go wrong

Irregular uneven surfaces do not make a joint fit to function. Special reamers, with the same curves as the gouges have been designed for the pur pose of making the new joint surfaces smooth and congruous. These again work in the dark, but they work safely and efficiently

Many other instruments have been designed from time to time, each aiming to overcome some technical difficulty so that we can now say we no longer miss the carpenter's bench or his vise.

Results

Malum Coxae Senilis.—The problem to be solved is that of a mechanically defective joint with secondary changes characteristic of traumatic arthritis. The bony changes are those of overgrowth resulting in mechanical interfer ence with joint movement. The acetabulum is commonly shallow and in a relatively lateral position. The head of the femur is misshapen, often de scribed as mushroomed with spur formation at the junction of the articu lar surface with the relatively heavier cortex of the neck. Both acetabulum and femoral head show areas of complete loss of articular cartilage. The soft tissue changes involve chiefly the synovial lining instead of being smooth and glistening it is corrugated with congested villi.

* From J. Bone and Joint Surg. 30-B 59 1948.

Fig. 763.—A. F Typical case of aseptic necrosis of the femoral head following subcapital *fracture of the neck of the femur* This patient had no internal fixation of the fracture. A mold arthroplasty was performed two years after injury because of increasing pain and disability (From Smith Petersen, M. N J Bone & Joint Surg. 30-B: 59 1948.)

Fig. 764—A. F Postoperative film, 3½ years after arthroplasty Patient now walks without a limp except when she is tired. She is self-supporting as a music teacher and is independent of help for any purpose whatsoever (From Smith Petersen, M. N J Bone & Joint Surg. 30-B: 59 1948.)

Operative treatment aims to create two relatively congruous joint surfaces and to guide bone repair by an inert mold. Such a mold serves also as a means of restoring smooth joint surfaces with a minimum of friction. A weight bearing joint is more stable and requires less muscular control if it is close to the center of gravity of the body consequently the acetabulum should be made as deep as possible

In exposing and remodeling the bony elements of the joint, the greater part of the soft tissues particularly the synovia, are sacrificed. The inferior and posterior synovia remain relatively undisturbed or intact. They are more accessible after the remodeling is finished and consequently the remaining synovectomy is done as a final procedure. In general the results are very favorable the majority of patients became independent of the help of others and able to lead an active life (Figs. 754, 755)



A B

Fig. 755.—A T A Preoperative film woman of 5 with a history of having fractured her hip 2 years previously It was treated by internal fixation. The three-flanged nail was removed a year later Extensive aseptic necrosis is evident there is, however, survival of sufficient femoral neck to make a modified Whitman reconstruction possible. *B* Postoperative film of the same patient. The acetabulum is shallow if it had been excised more extensively the hip joint would have been closer to the center of gravity of the trunk and a stronger mechanical relationship would have resulted. The functional result is however very satisfactory allowing patient to lead an active life independent of the help of others.

Rheumatoid Arthritis.—The problem to be solved depends upon the phase of the disease The predominant opinion of the internists is that operative treatment of any rheumatoid joint must be delayed until the disease has burned itself out or become quiescent, as judged by the sedimentation rate or acuteness of joint reactions. Recumbency or [illegible] treatment carried out for months or years, results in bone and mus[illegible] contractures and loss of elasticity of ligaments, fascia and in[illegible] septa. Arthroplasties undertaken under such unfavorable condi[illegible] e sufficient function to allow the patient to become ambulatc[illegible] h limited function will improve the character of the bony a[illegible] so that secondary arthroplasties or revisions can be undertak[illegible] able gain in the range of motion (Figs. 756-759)

The results of [illegible] treatment relat[illegible] e course of the disease are more [illegible] revisions of th[illegible] oplasty are le[illegible] frequent (Figs. 760[illegible]



Fig. 66.—H P A typical result of a fractured hip treated by too much internal fixation—two wood screws were introduced. Both the head and neck of the femur have been absorbed. X ray was taken five years after injury (From Smith Petersen, M. N J Bone & Joint Surg. 30-B: 59 1948.)

Fig. 67.—H. P Four years have elapsed after a modified Colonna operation. A mold has been placed over the greater trochanter The ilium has been osteotomized vertically in order to extend the acetabular roof laterally The lesser trochanter has been partially excised to prevent impingement on the posterior lip of the cotyloid notch. Patient i free from pain nd has a range of n tion more than sufficient for all purposes. Her hip is relatively weak. *She uses a cane for distance walking but never in the house.* (From Smith Petersen, M. N J Bone & Joint Surg 30-B: 59 1948)

Complications of Fractured Hips.—The problem to be solved depends upon the "complication." There are three main complications

1 Aseptic necrosis of varied extent
2 Dead femoral head with nonunion
3 Nonunion with a dead head and absorption of the distal neck

A routine arthroplasty, as described for malum coxae senilis, is indicated in patients with aseptic necrosis of minor extent. If the necrotic area is ex

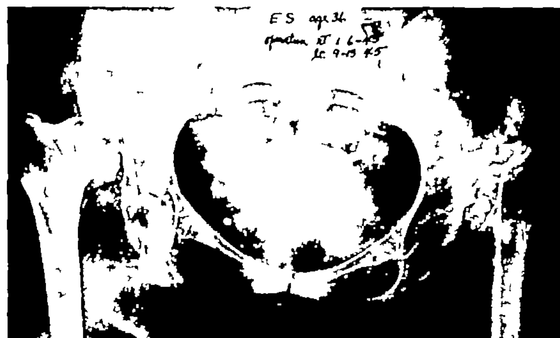


Fig. 768.—Preoperative film of a woman of 36 with bilateral dislocation of the hips. Patient complained of increasing disability because of pain in the region of the low back as well as in the hips. (From Smith Petersen, M. N. J Bone & Joint Surg. 30-B: 59, 1948.)



Fig. 769.—Postoperative film of same patient (Fig. 768) 2½ and 3 years later. Both hips have been placed in improved functional positions they are now at the same level and closer to the center of gravity of the trunk, i.e., they have been transplanted medially. On the left the greater trochanter has been transplanted distally in order to compensate for the *distorted femoral neck*. On the right such a procedure was not indicated. Functional result is satisfactory because of relief of pain and increased ability to lead a normal, independent life. (From Smith Petersen, M. N. J Bone & Joint Surg. 30-B 59 1948.)

tensive it is advisable to fill it in with cancellous bone grafts from the iliac crest (Figs. 763 764)

A modified Whitman operation is indicated when the distal femoral neck survives to sufficient extent to allow for reconstruction after transplantation of the greater trochanter (Fig 765)

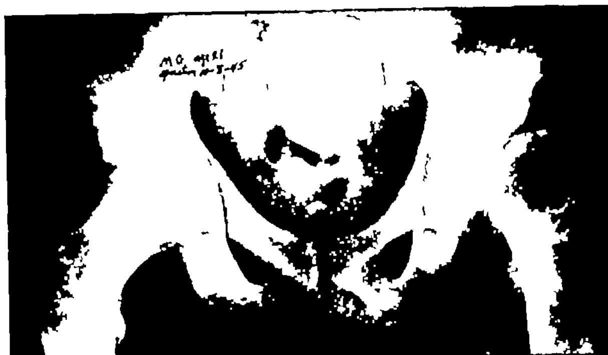


Fig. 770—Preoperative film of a young man of 21 with Legg-Calvé-Perthes disease involving the left hip. Patient complained of increasing disability because of local pain and decreasing mobility of the hip.



Fig. 771—Postoperative film of same patient (Fig. 770) 3 years later The acetabulum has been deepened bringing it closer to the center of gravity of the trunk the head and neck have been reshaped so as to fit loosely into the mold.

A modified Colonna operation is indicated when there is nothing left to reconstruct. Transplanting the greater trochanter covered by a mold, into the acetabulum results in a joint with sufficient motion for all purposes. It is

however a relatively weak joint because of diminished muscular leverage (Figs. 766-767)

Congenital Dislocation of the Hip in the Older Age Group—The problem to be solved has two main aspects, instability and shortening The instability is due to the *lateral displacement of the femoral head with loss of muscle power* and stable fulcrum Operative treatment therefore, must aim to correct the lateral displacement and increase muscular leverage by replacing the femoral head distally and mesially

By exposing *the mesial as well as the lateral aspects of the hip joint*, improved mechanical conditions can be created resulting in stability of fulcrum and increased muscular leverage (Figs. 768-769)

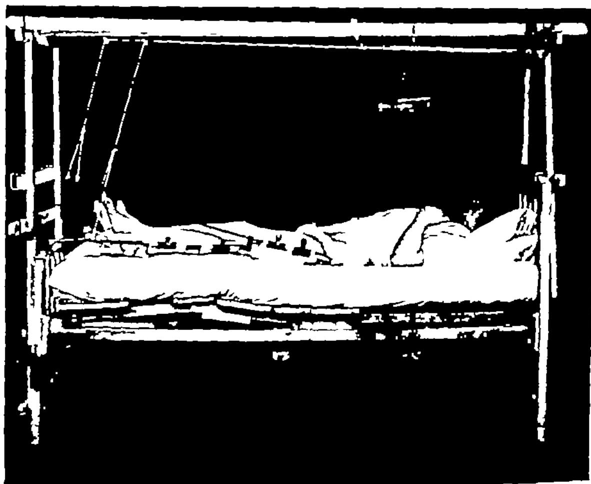


Fig. 772.—Postoperative position. Note (a) Angle of pull of traction and suspension ropes (5 pounds) (b) Half ring of splint clears thigh. (c) Knee slightly bent and joint of splint 1½ inches above the joint line.

Legg-Calvé-Perthes Disease.—The problem to be solved is a very instructive one It involves the result of a mechanically defective weight bearing joint, due to faulty development of unknown origin. Such a joint undergoes increasing degenerative changes because of its faulty mechanics and the inevitable result is limitation of activities because of pain (Fig 770-771)

The problem involved in slipped upper femoral epiphyses is essentially the same—that of creating a stable joint with sound mechanics.

Other Conditions—During the developmental years of mold arthroplasty it was used in the treatment of conditions for the relief of which there was no

satisfactory operation The experience gained during this period was encouraging and offered evidence to prove that the underlying principle was sound The advent of the Vitallium mold stimulated application of this operative procedure during the past ten years it has been used in 500 cases and the conditions treated include practically all to which the hip joint is subject



Fig. 7 3—Hip should be kept abducted. Note (a) Level pelvis. (b) Trunk in middle of bed. Favor leaning toward operated hip.

Postoperative Treatment of Mold Arthroplasty of the Hip

Attention to detail and careful supervision of the hip from time of closure of the wound until the leg is placed in a splint in traction are essential.

Position The extremity must be kept in abduction and at least neutral so far as rotation is concerned, the amount of abduction and rotation depend upon the relationship secured at the time of operation.

Dressing An elastoplast strapping is applied over the surgical dressing this must start well below the trochanter posteriorly and extend beyond the midline anteriorly Tight dressings are to be avoided.

Traction (5-7 lbs.) suspension in splint for four to six weeks (Fig 772 773)

Exercises during recumbency period include Quadriceps setting anterior tibial pull with toe curling gentle internal rotation.

Passive changes in position Sitting in maximum comfortable flexion and lying in maximum comfortable extension for definite periods.



Fig. 774.—A method of setting up the roller skating exercises with controlled weight resistance. Additional ropes to assist in passive abduction are also used by having pulleys attached to the ends of the skating board.

Active changes in position are to be encouraged.

1 Roller skating exercises are started in the fifth week after removal of the extremity from splint and traction (Fig 774) These are done twice a day for a few minutes to half an hour It is important to avoid fatigue.

2. Getting out of bed In the fifth week after two or more days of roller skating

A. The first time out of bed the patient is allowed to sit for a few minutes in a chair Two assistants are required for the first steps from the bed to a fairly high firm armchair One of these assistants should be a surgeon well acquainted with the hip

2 The second day up—walk with assistance—a few steps about the room Partial weight bearing

3 The Walker As soon as possible the patient is instructed in the use of a mechanical walker This can usually be done on the second or third day out of bed

4 The stationary bicycle This form of exercising is as a rule possible toward the end of the fifth postoperative week It is not always possible for the patient to go through a complete revolution of the pedals but even see sawing back and forth is beneficial Do not overdo this exercise start with a few minutes and increase gradually to fifteen minutes three times a day Rocking in a rocking chair involves somewhat the same principle and is an excellent form of exercise

5 Crutches The change from the walker to crutches depends upon the patient s ability to control the operated extremity and walk with confidence The use of crutches must be continued for a period of at least six months

6 Discharge from the Hospital Six to eight weeks after the operation for unilateral cases, eight to ten weeks for bilateral

7 A Routine of exercises and rest after discharge

Bicycling
Roller skating
Walking
Rocking in a rocking chair

B Frequent check ups for two years or more on gait motions, and muscle power

C Add stretching exercises, particularly aiming to increase and strengthen abduction flexion, extension and internal rotation

Gentle stretching in flexion and extension as well as abduction and rotation can be carried out at the end of two months without fear of dislocation or subluxation. Such stretching exercises are done two to three times a day to obtain an increased range of motion in the directions indicated and should be carried out as long as more motion is desirable Gentleness, slowness, and persistence in stretching is the only way to gain increased range of motion Forceful vigorous, repeated traumatic types of stretching will increase the amount of muscle spasm and diminish motion Stretching that produces pain uncontrolled by aspirin or pain that persists after exercising is too vigorous

Analyze all complaints and properly evaluate them. Muscle aches and pains are bound to occur but if muscle attachments remain sore all the time the explanation is commonly a faulty gait or overexercising Treatment for such persistent pain consists in diminished, but not discontinued activity heat and aspirin

The above outline is dogmatic The surgeon *must* vary the postoperative treatment according to the temperament of the patient and the mechanical result achieved at the time of the operation.

THE TEMPOROMANDIBULAR JOINT

Ankylosis of the temporomandibular articulation or jaw, is a serious disability The condition is virtually always induced by a pyogenic infection, the process usually osteomyelitis, occasionally *invades* even the ramus of the mandible. The affected portion of the mandible hypertrophies, often becoming two or three times normal size and is increased in density The joint

space is obliterated, permitting the bony surface of the condyle to merge with that of the temporal bone As dental hygiene is not possible severe oral sepsis is always associated

The affected side may be distinguished from the unaffected side by its somewhat smaller size Further *when motion is attempted, the chin moves* toward the unaffected side, and motion may be detected over the normal joint on palpation If both jaws are ankylosed of course no motion is possible Differentiation must also be made between *extra articular and intra articular* ankylosis. The external appearance of the two types is identical, but on retraction of the lips the true pathologic condition and cause of the inability to open the mouth are apparent.

There are no contraindications to arthroplasty of the jaw The disability is so distressing and embarrassing and the results so uniformly gratifying *that mobilization is warranted in every case*

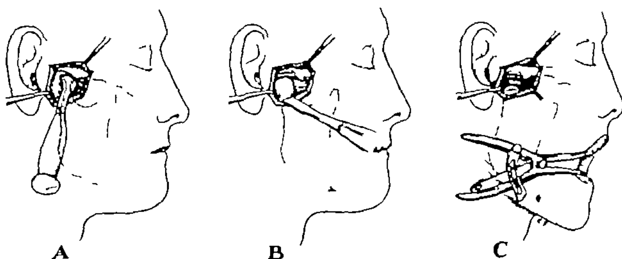


Fig 7 5—Arthroplasty of the temporomandibular joint. *A* After exposure by L-shaped incision, ankylosis is broken up. *B* Resection of one-half to three-fourths inch of the condyl *C* Cavity created in temporal bone and end of condyle smoothed to f rm a convex surface. *No fascia is interposed.*

The field of operation must be carefully prepared the hair being shaved for two or three inches over the temporal region. The external auditory meatus should be well cleaned sponged with alcohol and filled with sterile cotton

In unilateral ankylosis, either a local or general anesthetic may be given If the ankylosis is bilateral local anesthesia may be used and an arthroplasty performed on both jaws at the same time or if desired, the fusion may be severed and a new joint constructed on one side under local anesthesia then a general anesthetic may be administered during the operation on the opposite joint When a general anesthetic is chosen a tracheotomy set should always be available for immediate use

Campbell s operation is a *modification of Murphy s technic.*

Technic.—The incision is begun one half inch anterior to the external auditory meatus and extended along the zygomatic process for one and one-half inches. Dissection is carried *down to the zygoma, thence to the* anky losed temporomandibular articulation If this does not afford an adequate operative field, the incision is prolonged upward for one and one-half inches

at a right angle to the first portion, forming an L. The ascending branch of the facial nerve, which lies just anterior to the external auditory meatus must be carefully avoided. Upon exposure of one inch of the condyle the osseous fusion is severed with a chisel, the instrument should not be passed beyond the bone on the inner side as there is danger of a troublesome hemorrhage



Fig. 76.—A, Range of motion ten years after arthroplasty of the temporomandibular joint. B, C, D, Range of motion one year or less postoperatively, motion still increasing

from the internal maxillary or internal pterygoid arteries. One-half to three fourths inch of bone is excised from the condyle and its surface is remodeled to form a convex articular surface. A cavity is then excavated in the temporal bone. One may dispense with the interposition of tissue between the articular surfaces, as in unilateral ankylosis the articulation of the opposite

side holds the surfaces apart, and in bilateral ankylosis gravity and the weight of the jaw serve this purpose

After Treatment.—Active motion is instituted a few days after operation, or as soon as pain and tenderness have partially subsided. Full motion often is possible within a few weeks. Chewing gum is a convenient form of exercise. Physical therapy is a useful adjunct to restoration of motion, but is not essential as a good result may be obtained if the patient will cooperate. The jaws may be gradually separated by the daily insertion of a mouth gag, or an increasing number of tongue depressors between the teeth. When the space between the teeth will permit, a dentist should be engaged to repair the teeth and if necessary to restore the proper occlusion which may have been impaired by irregular development of the jaw or by excision of the bone at the joint.

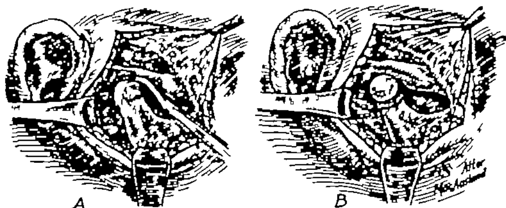


Fig. 777.—Arthroplasty of the temporomandibular joint (technic MacAusland) *A*, Joint remodeled to conform to normal anatomy *B*, Free transplant of fascia placed over condyle of mandible. (Redrawn from MacAusland, W R., and MacAusland, A. R. The Mobilization of Ankylosed Joints by Arthroplasty Philadelphia, 1929 Lea & Febiger)

Technic (Murphy).—The temporomandibular joint is approached through an L-shaped incision which extends in the perpendicular position downward to the upper border of the zygoma, thence forward along the upper margin of the zygoma for one-half to three-fourths inch. After separation of the tissues, two curved periosteal elevators are passed behind the neck of the mandible from side to side completely encircling the bone These instruments not only serve as retractors, but prevent injury to the internal maxillary artery which closely approximates the neck of the mandible. With a chisel, the bone is divided at the level of the tubercle and one-third inch of the neck is resected No attempt is made to remove the articular surface of the condyle of the mandible because of the possibility of penetrating the base of the skull. The mouth is then forcibly opened by the anesthetist. The perpendicular incision is elongated, and a U shaped flap of fat and fascia three-fourths inch wide and one half inch long is elevated from over the temporal muscle with its base attached at the upper margin of the zygoma. This fascia is folded down and packed into the cavity to reline the joint between the two fragments of the mandible Several small sutures anchor the fascial strip in place

MacAusland remodels the surfaces to conform as nearly as possible to the anatomic contour and inserts a free fascial transplant around the remodeled articular surface of the mandible.

THE SHOULDER

Arthroplasty for ankylosis of the shoulder has been performed in a small group of young individuals with the joint ankylosed in malposition. Results were generally disappointing. Fortunately, ankylosis of the shoulder is usually extra-articular and responds to more conservative measures (p. 1046). Further, because of the compensatory motion in the shoulder girdle and scapula, a shoulder joint ankylosed in a serviceable position is not inconsistent with satisfactory function. Limited motion or ankylosis secondary to comminuted fractures or fracture-dislocations of the shoulder are best treated by the Jones tendoplastic operation (p. 472) rather than by an arthroplasty of the shoulder.

THE ELBOW

Ankylosis of the elbow, as of other joints, usually is induced by an acute pyogenic infection. Trauma, however, is followed by osseous fusion in the elbow more frequently than in any other joint. Ankylosis in acute flexion is rarely observed; the position varies from 90 degrees' flexion to full extension.

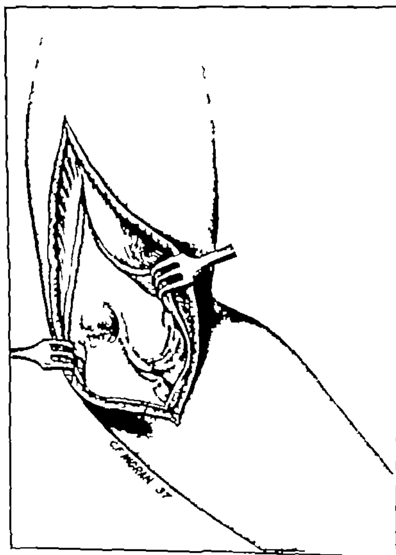


Fig. 778.—Arthroplasty of the elbow. Exposure of ankylosed joint; triceps aponeurosis incised in midline and retracted medially and laterally.

Contraindications to arthroplasty of the elbow are few In ankylosis from tuberculosis excision is preferable fortunately tuberculosis seldom invades this joint. A change in the structure of the bone as, for example, dense eburnation following osteomyelitis, or osteoporosis, may to some extent diminish the prospect of success, but by no means contraindicates arthroplasty in the elbow as in the weight bearing joints.

Technic.—Beginning above the elbow joint, an incision six to eight inches in length is made on the posterior aspect of the arm and forearm, just external to the midline The deep fascia is elevated laterally one inch bringing into view the broad aponeurosis of the triceps muscle This structure is severed transversely at the upper extremity of the incision and divided along

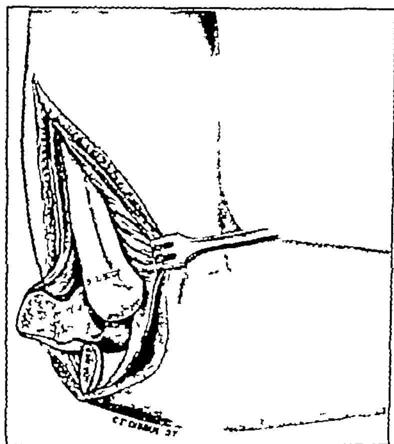


Fig. 79—Articular surfaces of elbow joint remodeled, forming one humeral condyle.

the internal and external borders or the aponeurosis may be incised longitudinally and retracted By dissection from above downward a long tongue of dense fascia is formed, with its attachment at the tip of the olecranon process. An incision is then made in the midline passing through the muscular fibers of the triceps and periosteum over the lower third of the humerus. With an elevator the periosteum is stripped from the lower third of the posterior surface of the humerus and the head of the radius and the olecranon process are exposed Fusion between the olecranon and humerus, and radius and humerus is severed with an osteotome the ulnar nerve being carefully protected The joint is then flexed and dislocated to the mesial aspect The lower extremity of the humerus is fashioned into one condyle convex from before backward no attempt is made to reproduce the contour of the capi-

tellum and trochlea With a curved chisel the superficial bone is excised from the sigmoid cavity and the head of the radius is denuded to the level of the inferior portion of this cavity All surfaces are smoothed with a rasp A strip of fascia lata of sufficient size to cover the remodeled joint is removed from the lateral aspect of the thigh The fascia is folded in half lengthwise, with the rough surface on the outside, and the folded edge is anchored to the anterior capsule by three chromic catgut stitches one on each side and one in the center The proximal fold of the transplant is then reflected over the condyles of the humerus. The lateral edges are sutured to the adjacent soft tissues well over the margin of the humerus, by interrupted stitches, if the soft tissues are inadequate the fascia may be held in place by sutures passed through holes drilled in the medial and lateral borders of the humerus The new sigmoid cavity is next covered by the distal half of the transplant, forming a closed sac which simulates that of the normal joint

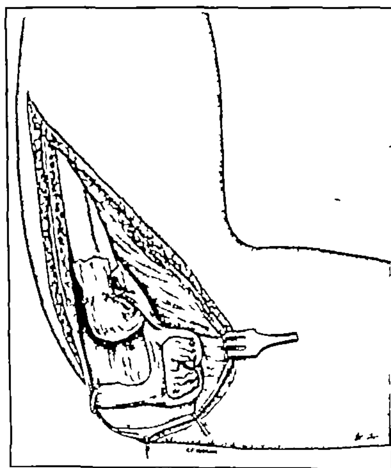


Fig. 719 —Fascia lata interposed between articular surfaces of ulna and humerus, and radius and ulna.

In the presence of synostosis between the ulna and radius, sufficient bone is excised to permit free rotation of the radius. A fold of the fascia is then reflected between the radius and ulna and the head of the radius is *invested* or a separate sheet is placed about the head and retained by a *purse-string* suture The articulation is reduced and the capsule closed from below upward the elbow being flexed at a right angle The tongue of the triceps aponeurosis if severed is sutured at a lower point than its former attachment, to permit free play of the joint in flexion.

Contraindications to arthroplasty of the elbow are few In ankylosis from tuberculosis, excision is preferable fortunately tuberculosis seldom invades this joint. A change in the structure of the bone as, for example, dense eburnation following osteomyelitis, or osteoporosis, may to some extent diminish the prospect of success, but by no means contraindicates arthroplasty in the elbow as in the weight bearing joints.

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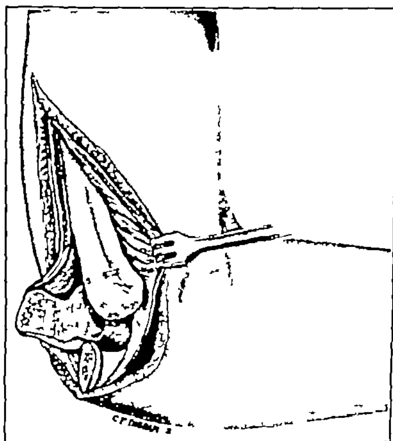


Fig 79—Articular surfaces of elbow joint remodeled, forming one humeral condyle.

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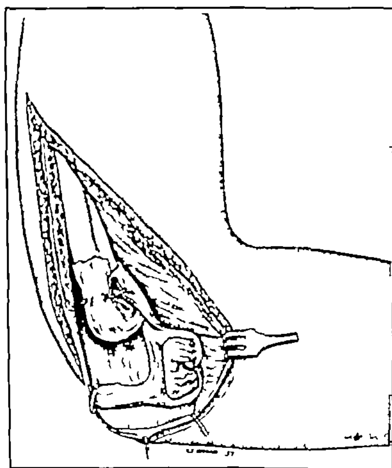


Fig. 780 —Fascia lata interposed between articular surfaces of ulna and humerus, and radius and ulna.

In the presence of synostosis between the ulna and radius, sufficient bone is excised to permit free rotation of the radius A fold of the fascia is then reflected between the radius and ulna and the head of the radius is invested, or a separate sheet is placed about the head and retained by a purse-string suture The articulation is reduced and the capsule closed from below upward the elbow being flexed at a right angle The tongue of the triceps aponeurosis if severed is sutured at a lower point than its former attachment to permit free play of the joint in flexion

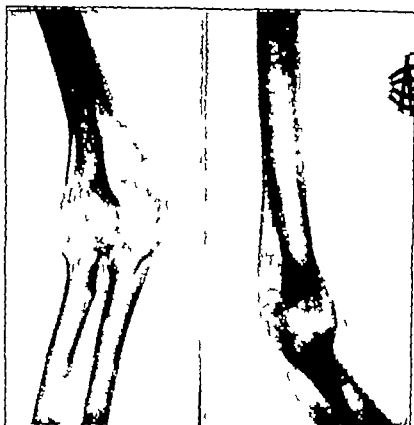


Fig. 781.—Solid bony ankylosis of elbow joint in patient aged 11 years.

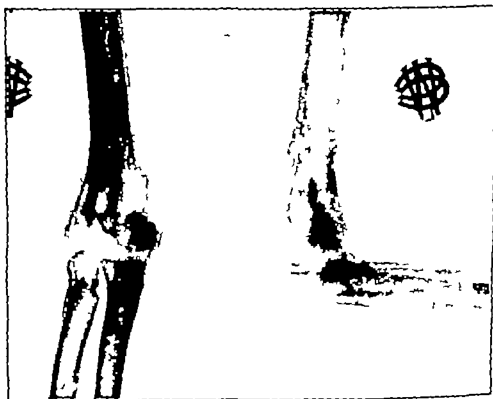


Fig. 782.—Same patient as shown in Fig. 781 after arthroplasty of the elbow

If the supply of fascia lata has been exhausted, the aponeurotic tongue of dense fascia may be used for interposition between the articular surfaces

After Treatment.—The elbow is immobilized in a right angle splint or cast and so maintained for a period of ten days or two weeks When healing is complete, the splint or cast is removed every two hours and active and passive motion are practiced for a few minutes with the aid of special apparatus (Fig 63)



Fig. 783—Same patient as shown in Figs. 781 and 782, four months after arthroplasty



Fig 784—Ankylosis of elbow followed compound fracture. Practically normal flexion and extension one year after arthroplasty fifty per cent of normal pronation and supination.

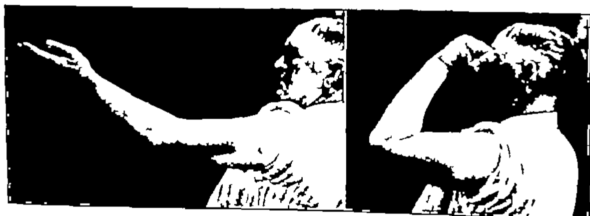


Fig. 785.—Ankylosis followed fracture of elbow in patient aged 56 years. Sixty degrees of free active motion present six years after arthroplasty

Technic (MacAusland).—Beginning above the external condyle, an inverted U incision is made over the olecranon process to the internal condyle. The olecranon is divided transversely one inch from its tip and, with a soft tissue flap is turned proximally. The ankylosis is broken up and the humerus remodeled with rongeurs, forming a trochlear or intercondylar surface. With a rasp or file the olecranon fossa is slightly enlarged toward the joint sufaec. The ulna is then excavated by means of a curette or rasp and made to fit accurately over the reconstructed surface of the humerus. A free transplant of fascia lata is applied over the newly formed humeral condyles and fixed by chromic catgut sutures, its rough surface being placed in contact with the bone. The remaining part of the flap is brought over the cavity in the ulna, then folded back on the humeral shaft as far as the olecranon fossa. (Originally, MacAusland interposed only a single layer of fascia over the humeral condyles.) Two holes are drilled, one in the olecranon and one in the shaft of the ulna, through which a suture of No. 2 chromic catgut is passed to hold the olecranon in close approximation with the ulna.

After Treatment.—(See p. 1117.)

THE WRIST

Arthroplasty is employed most often when the wrist is fused in extreme flexion and supination and pronation are limited. For an accompanying derangement of the distal radio-ulnar joint Darrach's resection (p. 597) is an

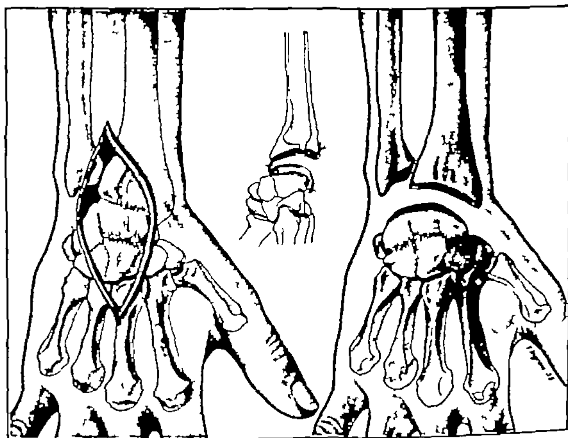


Fig. 786.—Arthroplasty of the wrist joint. Dorsal incision, fusion between carpus and radius broken up and joint surfaces remodeled. Detail shows fascia interposed between articular surfaces.

appropriate supplementary procedure. The operation described below is essentially a resection rather than an arthroplasty. Although the degree of motion ultimately restored may be comparatively less than that obtained in other joints, the ability to dorsiflex the wrist even slightly affords material improvement in function of the fingers and thumb. As a rule, the joint is ankylosed in the most serviceable position, i.e., slight extension; arthroplasty is not advisable.

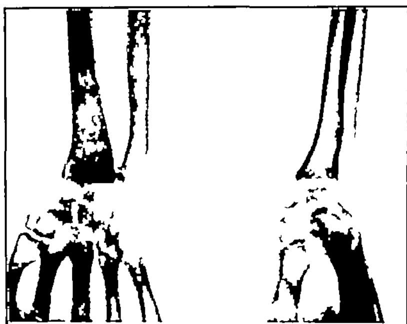


Fig. 787.—Roentgenogram of wrist following arthroplasty.

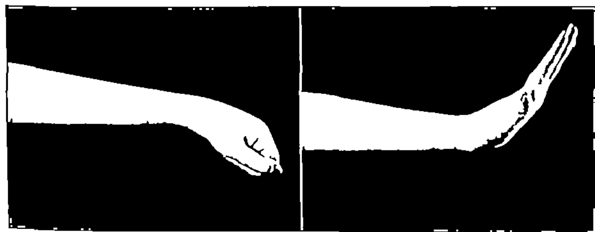


Fig. 788.—Flexion, 1 0 degrees; extension, 150 degrees. Free range of motion of fingers after arthroplasty.

Technic.—An incision four inches in length is made in the midline on the dorsum of the wrist, beginning at the base of the third metacarpal bone. The deep fascia is excised and the extensor tendons to the fingers and thumb are separated, removed from their grooves in the dorsum of the radius, and retracted medially and laterally. The dorsal ligaments of the wrist are incised longitudinally and the ankylosed carpus is exposed by subperiosteal dissection. Fusion between the carpal bones and the radius is severed with a curved chisel. The distal end of the radius is remodeled to form one concave

Technic (Fowler) —The joint is exposed by a longitudinal dorsolateral incision approximately 5 cm in length between the interosseous and extensor tendons. *The extensor tendon must be completely freed from its adhesions* to the metacarpal bone, though its attachment to the phalanx is not disturbed A joint space is created by excision of a substantial segment of the base of the proximal phalanx the metacarpal head is fashioned to incline somewhat volar ward being tapered sharply in an anteroposterior direction Laterally the reconstructed articular surface is broad and flat The phalanx is cut transversely, no attempt being made to create any concavity in its new articular surface Interposition material consists of a layer of thin fascia or of paratenon from over the fascia lata on the anterolateral aspect of the distal third of the thigh This membrane is interposed between the joint surfaces beneath the extensor tendon proximal to the joint and deep to the tendons of the interossei

If intrinsic muscle function is lost the flexor digitorum sublimus should be removed from the flexor tendon sheath rerouted through the lumbrical canals on each side of the affected joint and sutured to the extensor aponeurosis on each side of the proximal phalanx, as described by Bunnell

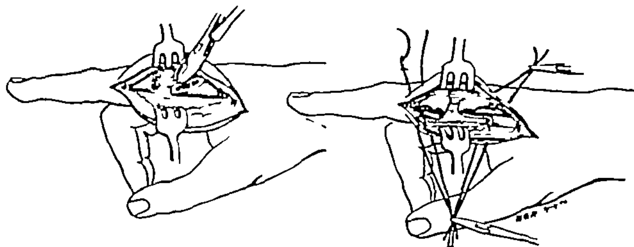


Fig. 19.—Fowler technic of arthroplasty of metacarpophalangeal joint. Proximal phalanx severed transversely Metacarpal tapered on flat. Fascia interposed and fixed between joint surfaces. (From Fowler S. B. J Bone & Joint Surg. 29: 193 1947)

After Treatment.—A cast is applied with traction to the affected digits maintaining the metacarpophalangeal joints in 60 degrees flexion. Seven days postoperatively mobilization of the joint is begun Three weeks after operation all support is removed and the exercises are increased Should there be resistance to full flexion a removable traction splint is applied to increase the range of motion The splint is worn only at intervals and is gradually abandoned as motion increases.

THE PHALANGEAL JOINTS

Mobilization of the middle or distal finger joints is subject to considerably more limitation than the metacarpophalangeal joints. Bunnell points out that the collateral ligaments of the middle finger joints are tight at a right angle flexion. When the joints become stiff in a position greater or less than a right angle the collateral ligaments contract severance of these ligaments is necessary before the joint can be extended from an extreme flexed posi

articular surface, and the articular surface of the carpus is made convex to conform accurately to the contour of the end of the radius. Sufficient bone is removed from the carpus to provide a space of three-eighths inch between the joint surfaces when traction is exerted If pronation and supination are limited by a synostosis between the radius and ulna, the distal end of the ulna is resected.

A strip of fascia lata two and one half inches wide and four inches long is removed from the thigh. With its rough surface outward, the fascia is folded in half lengthwise and inserted between the remodeled bony surfaces. The folded edge is anchored to the anterior capsule by two chromic catgut sutures, one on each side of the joint. The distal half of the transplant is reflected over the remainder of the carpus to the bases of the metacarpal bones, while the articular and dorsal surfaces of the radius are covered with the proximal portion. The extremities of the transplant are stitched by inter rupted chromic catgut sutures to adjacent fascial or periosteal tissues.

After Treatment—The wrist is immobilized in moderate dorsiflexion by means of a metal cock up splint. The forearm should be elevated to expedite recovery from the postoperative reaction After ten days or two weeks, passive and active motion and physical therapy are instituted and gradually increased. Between exercise periods, the wrist should remain immobilized in moderate dorsiflexion for three months.

Even though ankylosis recurs, the optimum position for function will have been established by this procedure.

JOINTS OF THE THUMB

Ankylosis of the carpometacarpal joint of the thumb may be associated with ankylosis of the wrist, or may follow comminuted fractures or infection involving this joint, but is exceedingly rare from any cause. If the thumb is in a serviceable position surgical intervention is contraindicated If the joint is ankylosed in the extended or abducted position, osteotomy is prefer *able to arthroplasty Essentially the same indications* are applied to the carpometacarpal joint and the distal joint of the thumb

METACARPOPHALANGEAL JOINTS

Fowler reports 16 arthroplasties of the metacarpophalangeal joints car ried out on 13 patients nine of these patients obtained at least 70 degrees of active motion. It was Fowler's opinion that the metacarpophalangeal joint of the fingers was most favorable for arthroplasty in that the joint is con cerned primarily with mobility is not subject to trauma from weight bearing and is under complete muscular control. Arthroplasty is indicated in the presence of a destructive lesion of the metacarphophalangeal joint, with less than 30 degrees of motion in a useful arc, provided mobilization of the joint will restore a practicable degree of function in the finger In the presence of a permanently anesthetic finger marked deformity or lack of flexor tendons, mere mobilization of the joint by arthroplasty does not improve the function of the hand and consequently is contraindicated. In the presence of excessive shortening of the metacarpal, arthrodesis may be preferable. Arthroplasty of the thumb was not considered advisable, and, in Fowler's series, was utilized only once in the little finger Limitation of motion in the metacarpophalangeal joint with intact joint surfaces is treated by a different technic (p 1050)

Technic (Fowler).—The joint is exposed by a longitudinal dorsolateral incision approximately 5 cm. in length between the interosseous and extensor tendons. The extensor tendon must be completely freed from its adhesions to the metacarpal bone, though its attachment to the phalanx is not disturbed. A joint space is created by excision of a substantial segment of the base of the proximal phalanx; the metacarpal head is fashioned to incline somewhat volarward, being tapered sharply in an anteroposterior direction. Laterally the reconstructed articular surface is broad and flat. The phalanx is cut transversely, no attempt being made to create any concavity in its new articular surface. Interposition material consists of a layer of thin fascia or of paratenon from over the fascia lata on the anterolateral aspect of the distal third of the thigh. This membrane is interposed between the joint surfaces beneath the extensor tendon proximal to the joint and deep to the tendons of the interossei.

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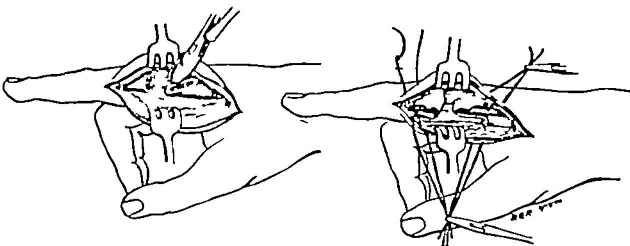


Fig. 789.—Fowler technic of arthroplasty of metacarpophalangeal joint. Proximal phalanx severed transversely. Metacarpal tapered on flat. Fascia interposed and fixed between joint surfaces. (From Fowler, H. B.: J. Bone & Joint Surg. 29: 193, 1947.)

After Treatment.—A cast is applied with traction to the affected digits maintaining the metacarpophalangeal joints in 60 degrees flexion. Seven days postoperatively mobilization of the joint is begun. Three weeks after operation all support is removed and the exercises are increased. Should there be resistance to full flexion, a removable traction splint is applied to increase the range of motion. The splint is worn only at intervals and is gradually abandoned as motion increases.

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tion, or flexed from an extended position Unfortunately capsulotomy which is so successful when performed for the proximal finger joint (p 1050) is less efficacious in the middle finger joints

The same tenets hold true for intra-articular ankylosis of the interphalangeal joints. *Following arthroplasty, lateral motion is difficult to control* angulation may take place followed by a valgus or varus deformity Further with intra articular ankylosis, the periarticular structures necessary to mobilization of the joint are seldom normal.

Bunnell advises amputation of the finger through the middle joint, or shortening of the finger by arthrodesis of the middle or distal joint with the finger in semiflexion thus keeping it out of the way In exceptional cases, arthroplasty of a middle finger joint may be tried provided the adjacent soft tissue structures are normal Bunnell recommends that the incision be placed laterally and away from the lateral bands of the dossière creating a space of at least one-third inch between the ends of the reconstructed bones. Post operatively the joint should be maintained in flexion with traction.

Surgery for mobilization of the distal finger joint is practically never advisable

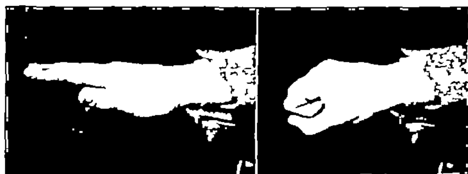


Fig 790—Range of motion practically normal following arthroplasty of third metacarpophalangeal joint.

MULTIPLE ANKYLOSES

Arthroplasties in multiple ankyloses following pyogenic infection present a more difficult problem by far than the mobilization of a single joint. The technic in each joint differs from that followed in single ankylosis only in that the bone is generously excised even at the expense of stability in order to insure motion Should both the upper and lower extremities be involved, the ankylosed joints of the upper extremity should be mobilized first that the patient may use them in carrying out exercises of the joints of the lower extremity after operation. Further the joints of the upper extremity must be sufficiently restored to permit the use of crutches when walking is begun; otherwise the natural development of function in the new joints of the lower extremity will be impossible

A general sepsis, as well as reactivation of the local process, takes place much more often than when ankylosis is confined to a single joint Also recurrence of the ankylosis is more likely Nevertheless, multiple ankyloses are so disabling that arthroplasty is worthy of trial even though only a small degree of function may be produced. A successful result may be obtained after repeated recurrences of ankylosis. For example, following six arthro-

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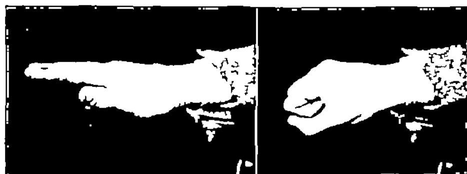


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Fig. 791.—Bilateral ankylosis of hips induced by infectious arthritis.

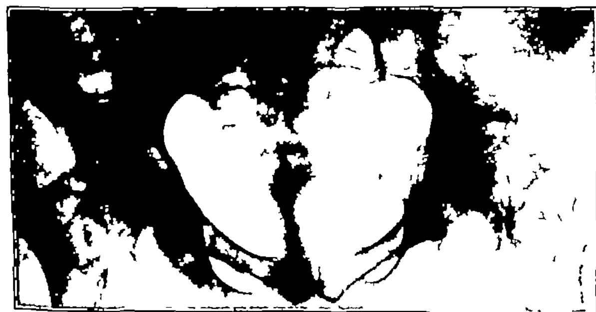


Fig. 792.—Same patient as shown in Fig. 791 six months after bilateral arthroplasty of the hips.

Fig. 793.—Satisfactory function of both hips and left knee after six arthroplasties.

Fig. 794.—*A* Solid bony ankylosis of knee. *B* One year after arthroplasty *C* Eleven years after arthroplasty Patella is fused to tibia. Excellent joint space, with fairly smooth articular surfaces.

plasties one of Campbell's patients was rewarded with function in two hips and one knee, and thus was enabled to carry on relatively normal activities

In atrophic rheumatoid, or progressive polyarticular ankylosing arthritis, arthroplasty is always more or less experimental, in fact, the operative technic is that of excision rather than a real arthroplasty When feasible, the process should have entirely subsided Obviously a joint which presents acute manifestations is not a propitious field for arthroplasty Since the process may be active for several years before symptoms completely disappear, however in certain cases operative procedures may be undertaken before the disease has been arrested and a residual status is reached

In approximately 30 per cent of Campbell's cases multiple arthroplasties have been successful to a gratifying degree From being chair ridden patients with multiple ankyloses of the lower extremities have been enabled to walk with or without crutches, and a corresponding improvement has been afforded those whose upper extremities were affected

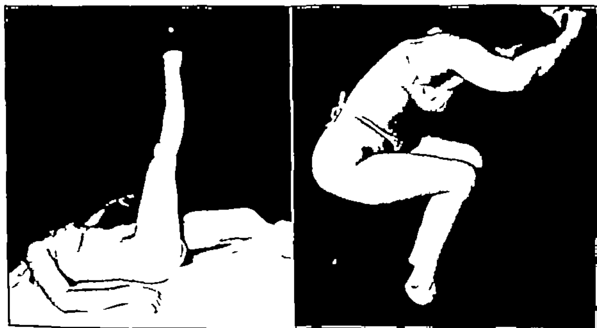


Fig. 791.—Same patient as shown in Figs. 794 and 741. Practically normal range of motion in right knee and hip eleven years after arthroplasty of both joints.

References

Albee, Fred H Original Features in Arthroplasty of the Knee With Improved Prognosis, Surg Gynec. Obst. 47 312, 1928.

— The Principles of Arthroplasty J A. M A. 98 245, 1931

Baer W S. Arthroplasty With the Aid of Animal Membrane Am. J Orthop. Surg 16 1, 1918.

—: Arthroplasty With the Aid of Animal Membrane J Orthop Surg 3 421, 1921

—: Arthroplasty of the Hip, J Bone & Joint Surg 8 769 1926

Bick, Edgar M. Source Book of Orthopedics, Baltimore 1937 Williams & Wilkins Co.

Bunnell, S. Surgery of the Hand, Philadelphia, 1944 J B Lippincott Co.

Campbell, Willis C Arthroplasty of the Knee Report of Cases, J Orthop Surg 3 430 1921.

—: Arthroplasty of the Elbow Ann. Surg 76 615 1922.

— Mobilization of Joints With Bony Ankylosis An Analysis of 110 Cases, J A. M A. 83 976 1924

—: The Present Status of Arthroplasty Surg Gynec. Obst. 41 843 1925

— The Physiology of Arthroplasty (Sir Robert Jones Lecture) J Bone & Joint Surg 13 223 1931

— Mobilization of the Ankylosed Jaw J Am. Dent. A. 19 1222 1932.

— Surgery of the Ankylosed Joint, Surg. Gynec. Obst. 55: 747, 1932.
—: End Results in Arthroplasties of the Hip J Michigan M. Soc. 33 49, 1934.
Campbell, W C. Interposition of Vitallium Plates in Arthroplasties of the Knee Am. J Surg 47 639 1940.
Dickson, Frank D The Mobilization of Ankylosed Joints by Operation, J Missouri M. A. 20 266, 1923.
Fowler S. B.: Mobilization of Metacarpophalangeal Joint, J Bone & Joint Surg 29 193 1947
Groves, E. W Hey Arthroplasty Brit. J Surg 11 234 1923
Hark, F W Arthroplasty of the Knee Am. Acad. Orthop. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944 J W Edwards.
Haas, Julius Functional Arthroplasty of Elbow and Knee, Am. Acad. Orthop. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor, Michigan, 1944, J W Edwards.
Henderson, M. S. What Are the Real Results of Arthroplasty? Am. J Orthop. Surg 16: 30 1918.
— Arthroplasty Minnesota Med. 6 97 1923
Kirschner M. Die praktischen Ergebnisse der freien Fascien-Transplantation, Arch. f. klin. Chir 92 888 1910.
Koontz, Amos K. Dead (Preserved) Fascia Grafts for Hernia Repair J A. M. A. 89 1230, 1927
Law W A. Post-Operative Study of Vitallium Mould Arthroplasty of the Hip Joint, J Bone & Joint Surg 30-B 76 1948.
MacAusland, W R.: The Mobilization of Elbow by Free Fascia Transplantation, with Report of 31 Cases, Surg Gynec. Obst. 33 223, 1921
— Mobilization of Ankylosed Joints. Printed in Brussels, Imprimérie Medicale & Scientifique (S.A.) 1923.
MacAusland, W R., and MacAusland, A. R. The Mobilization of Ankylosed Joints by Arthroplasty Philadelphia, 1929 Lea & Febiger
Murphy John B. Ankylosis of the Hip Arthroplasty, Surg Clin. John B. Murphy 1 243, 1912.
— Arthroplasty Ann. Surg 57 593, 1913.
— Arthroplasty for Inter Articular Bony and Fibrous Ankylosis of the Temporomandibular Articulation, J A. M. A. 62 1783, 1914.
Payr E. Gelenksteifen und Gelenkplastik, Berlin, 1934, Julius Springer
Phemister D B., and Miller Edwin M. The Method of New Joint Formation in Arthroplasty Surg. Gynec. Obst. 26 406, 1918.
Putti, V Arthroplasty of the Knee Joint, J Orthop. Surg. 2 530 1920
— Arthroplasty, J Orthop. Surg 3 421 1921
— Personal communication.
Ryerson Edwin W Arthroplasty of the Elbow Joint, Am. Acad. Orthop. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944, J W Edwards.
Smith Petersen, M N Arthroplasty of the Hip. A New Method, J Bone & Joint Surg. 21: 269 1939
Smith Petersen, M. N : Evolution of Mould Arthroplasty of the Hip Joint, J Bone & Joint Surg 30 B 59 1948.
Smith Petersen M. N., Larson, C. B., Aufranc, O E., and Law W A.: Complications of Old Fractures of the Neck of the Femur Results of Treatment by Vitallium Mold Arthroplasty J Bone & Joint Surg 29 41 1947
Speed J S., and Knight, R. A. Arthroplasty of the Hip, Am. Acad. Orthop. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944, J W Edwards.
Speed J S., and Smith Hugh Arthroplasty A Review of the Past Ten Years, Internat. Abstr Surg 70 224 1940
Stooren, H. Experience and Results From Mobilizing Plastic Operations in Four Cases of Osseous Ankylosis of the Knee, Acta Orth. Scandinav 22 146 1947
Sudhoff W Anatomisch histologische Untersuchung eines Falles an Blutig Mobilisiertem Elbogengelenk. Beitr z. klin. Chir 123 633 1921
Venable C. S., and Stuck W G Electrolysis Controlling Factor in the Use of Metals in Treating Fractures, J A. M A. 111 1349 1938.

CHAPTER XVIII

MISCELLANEOUS AFFECTIONS OF BONES

This discussion will deal only with affections of the bones which are amenable to surgical treatment, namely, osteomyelitis, tuberculosis, fungus infections, syphilis, osteitis fibrosa cystica, both diffuse and local, rickets and tibia vara

INFECTIOUS (PYOGENIC) OSTEOMYELITIS

Osteomyelitis may involve one or several bones. Generally in children the process begins in the metaphysis adjacent to an epiphysis and extends along the shaft perhaps involving the entire length of the bone In adults, the process begins in the periosteal vessels of the shaft In other cases, the process is localized to one area in the bone forming a small cavity or Brodie s abscess.

The course of the disease may be divided into four stages acute subacute, chronic, and residual The operative procedures differ for each stage being based upon the constitutional symptoms and the local pathologic process, particularly as evidenced by successive roentgenograms. A familiarity with the clinical aspects, therefore, is necessary to an understanding of the rationale of treatment. These will be discussed in brief.

The acute stage begins with dramatic constitutional symptoms and ends with their disappearance. Before the introduction of antibiotics this stage of the disease usually continued for approximately six weeks. Under treatment with penicillin and other antibiotics the acute stage may subside within three to five days usually it lasts from one to two weeks, depending upon the susceptibility of the causative organism to the antibiotics used

During the first few weeks the roentgenogram is of little value in determining the diagnosis. In children who are not treated with antibiotics, early destruction of the affected bone and elevation of the periosteum with new bone may be seen within ten days to a few weeks after the onset of the disease. In adults, little reaction may be observed in the bone after the elapse of several weeks. With the use of antibiotics, changes as observed in the roentgenogram are less extensive and their appearance is delayed in fact, roentgenographic evidence of bone changes may not appear at all even though the clinical findings may warrant a diagnosis of acute osteomyelitis. In the latter event, a definite diagnosis of osteomyelitis cannot be made.

Formerly the subacute stage was characterized by destruction of bone usually extending throughout the entire shaft, and advanced osteoporosis. Numerous cavities honeycombed the bone and as a rule a massive involucrum surrounded large sequestra Since the antibiotics have come to be widely employed, these extensive bone changes are seldom observed Unless the process is arrested by proper medical and surgical treatment, however this stage of increasing bone formation and sequestration with discharging sinuses may persist indefinitely Continued activity of the infection is indicated by a low grade fever

In the chronic stage, constitutional symptoms subside and the reparative process continues. Sequestra are definitely localized and are discernible in the roentgenogram by a difference in density from the surrounding bone. Even the newly formed bone or involucrum may eventually sequestrate because of



Fig. 788.—Osteomyelitis of tibia in acute, subacute, and chronic stages.

a deficiency of the blood supply from reinfection. Usually the bone becomes sclerotic. Sinuses may lead from the skin surface directly to large cavities or to sequestra. The chronic stage of osteomyelitis may persist for years. During this period there may be an acute exacerbation of symptoms as a result of trauma or lowered general resistance.

deficient through the scar tissue, the slightest injury may impair the local blood supply and lead to necrosis or sequestration. Even after the skin and soft structures are entirely healed the roentgenogram may reveal one or more cavities within the osseous structure which may be filled with purulent material and sequestra. In other cases the cortex may be so dense as to obscure cavities or sequestra deep in the bone. These cavities may become active with or without external stimulus by trauma.

GENERAL TREATMENT OF OSTEOMYELITIS

See section on Management of the Septic Patient, Chapter I

OPERATIVE TREATMENT OF OSTEOMYELITIS

To prevent repetition, surgical procedures for osteomyelitis of the shafts of the long bones will be described only for the tibia, since with the exceptions mentioned later the principles of treatment for all are practically identical Exposures of the long bones are described in Chapter IV The treatment of osteomyelitis of the os calcis, lower third of the femur ilium, spine, and mandible, as well as resection of the bones of the feet, the fibula ilium, and ribs, will be discussed separately

Acute Osteomyelitis

The questions of the proper time and indications for operative treatment in the first or acute stage of osteomyelitis have been and still are subjects of considerable debate. A few years ago it was the general opinion that acute osteomyelitis should be treated as an emergency operation being performed early and that the bone should be extensively resected to relieve intermedullary pressure and establish thorough drainage. Starr in 1921 recommended a more conservative surgical approach. Since then, a great deal has been written regarding the relative merits of early and late operation for acute osteomyelitis.

Wilson, in 1935 and again in 1941 advocated delayed operation He stated that drainage was in order after all signs of dehydration had been overcome, when the location of the focus could be determined with some degree of certainty and when the presence of purulent material was reasonably evident Further he stated that the surgeon should never rush into an inexpedient operation simply because he has a patient with septicemia who has developed an abscess within the substance of the bone.

Key also in 1941 advocated operation as soon as the fluid balance could be restored to normal and the patient's general condition would permit surgery He recommended placing a small trap door in the bone for intraosseous drainage, regardless of the presence or absence of a subperiosteal abscess. He likewise advised against surgery in children under two years of age, as approximately 50 per cent of these have a streptococcic infection further the bone contains little inorganic substance and the sinuses are large The latter factors permit early spontaneous drainage of the bone into the surrounding soft tissue giving rise to an extraosseous abscess. In 1946 however Key expressed the opinion that early surgical drainage of the focus is no longer necessary nor even indicated since it is possible in most cases to clear the blood stream of bacteria and stop the progress of infection by chemotherapy in some cases the focus in the bone may be sterilized by chemother

apy alone He still advocated drainage of a definite soft tissue abscess including a small opening in the cortex of the bone for intraosseous drainage

Butler in an excellent review of 500 cases accumulated between the years 1919 and 1937, stated that in choosing between aspiration or incision of the periosteum, and incision of the periosteum and drilling of the bone as the local surgical treatment one should be guided by the findings in the individual case He urged close cooperation between the bacteriologist and the surgeon in determining the course to be pursued This advice has been partially heeded in the present treatment of the disease with antibiotics

Dickson in 1945 stressed the importance of distinguishing a localized bone abscess from osteomyelitis with septicemia and multiple abscesses. For a localized bone abscess, he recommended surgical drainage On the other hand in dealing with septicemia associated with inconclusive signs of a localized abscess in the bone or with signs of multiple abscesses surgery is contraindicated and may hasten a fatal termination He further stated that drainage if necessary should be thorough but should be established with a minimum of surgery He advocated an incision in the soft part over the point of greatest tenderness and removal of a cortical window approximately one inch square from the bone In his opinion incision and drainage of the periosteum without an opening in the cortex does not provide adequate drainage

Within recent years especially since the introduction of the antibiotics, the trend has been toward more conservative surgical treatment of acute osteomyelitis. At present it seems generally agreed that acutely ill patients with osteomyelitis, including those with septicemia should be treated with antibiotics that surgery should be postponed until the general condition of the patient will warrant the procedure and until a soft tissue abscess has formed and can be diagnosed clinically The abscess should be evacuated by multiple aspirations or by incision and drainage Whether or not a small cortical window should be removed for intraosseous drainage is still questionable it would appear however, that if incision to the bone is necessary for drainage of the soft tissue abscess little additional harm can be done by drilling four to six holes in the cortex and removing the intervening portion.

Drainage as applied to the tibia, and in a similar manner to other bones, is as follows

Technic.—An anteromedial incision three inches or more in length is made over the affected area of the tibia. The periosteum may be found completely detached from the bone by tension from a subperiosteal accumulation of purulent material In this event, the material will escape under pressure on incision of the periosteum If there is no subperiosteal accumulation, the periosteum is elevated from side to side a distance of one half to one inch, according to the size of the bone the stripping should be restricted to the minimum requirement, as the periosteal vessels carry nourishment to the bone and repair and involucrum formation will be delayed until revascularization is established. In the majority of cases, several holes are drilled through the cortex into the medullary canal to institute siphonage If purulent material exudes through the holes, a trap door one half inch wide and approximately one inch long is outlined with a drill producing as little trauma as possible and the cortex in this area is removed The marrow cavity thus exposed is sponged out gently all detritus being removed Curettage of the bone is not advisable This procedure is only for drainage purposes. Continued and adequate drainage of the medullary canal is maintained by packing the wound open with a

light petrolatum gauze The gauze should be placed in the wound loosely in order to promote rather than to obstruct drainage.

After Treatment.—With the extremity in the most useful position for future function, immobilization is effected by splints or plaster casts both distal and proximal to the bone involved. The petrolatum gauze drain is left in situ for a period of six weeks, *only the outside dressings being changed for clean* liness. The subsequent treatment is described in the discussion of the subacute chronic and residual stages.

Subacute Osteomyelitis

In neglected cases, the patient may first be observed after the partial subsidence of the acute stage of the disease as manifested by only a moderately high fever The exudate from a subperiosteal abscess may have broken through the periosteum and invaded the soft structures, causing large soft tissue abscesses. Frequently one finds that the soft tissue abscesses have been inadequately drained by small stab incisions under the erroneous impression that the condition was entirely a matter of infection of soft tissue Massive sequestration of bone may be present because of complete separation of the periosteum from the shaft of the bone and consequent interference with the blood supply Under these circumstances the patient should receive general restorative treatment, including necessary blood transfusions and an ample quantity of proteins Penicillin or some other antibiotic depending upon the organisms present should be given. Adequate drainage should be established and maintained until the patient s general condition warrants more extensive surgery The type and extent of surgical treatment to be given will depend upon the patient s response to supportive therapy

Chronic Osteomyelitis

The most vital point in the surgical treatment of chronic osteomyelitis is the selection of a technic which meets the requirements of the individual case. The procedure must be planned according to the area involved and the local reaction. The indiscriminate destruction of bone and stripping loose of large areas of periosteum is to be deplored, such measures do not prevent, but rather induce recurrence and uselessly prolong convalescence. Further sequestration is likely to continue following such an operation, leading to a never ending chain of recurrences and operations. One must also have due regard for the future growth and repair of bone by avoiding surgery adjacent to the epiphyseal line, so far as possible.

If the constitutional symptoms, such as elevation of temperature, indicate an exacerbation of the acute infection, more thorough drainage must be established. *Radical operations should be undertaken only when,* in the roentgenogram living bone can be distinguished from dead bone and there is a sufficient amount of involucrum to form a support which will maintain length and contour despite the removal of large sections of necrotic bone or sequestra.

There is at present a tendency to ignore large sequestra in anticipation of their absorption or extrusion through the sinus. Although such a course may be justified in some cases when all the sequestra are small, large sequestra should always be removed surgically to prevent an indefinitely prolonged convalescence. The operation is not urgent, however but may be postponed so long as the patient improves.

Sequestra may vary in size from minute particles to the entire circumference of the shaft of the bone. They are demonstrated in the roentgenogram by their density, which remains normal. In contrast, the surrounding new bone is much less dense, as is also the original living bone wherein osteoporosis or atrophy has taken place. Sequestra or cavities may be obscured, however, by dense sclerotic bone. In osteomyelitis of long standing a portion of the involucrum or new bone may itself become a sequestrum and, being of the same density as the surrounding bone, may render the differentiation from viable bone difficult. Failure to recognize this type frequently is responsible for persistence of the disease. When detached masses of new bone are observed, therefore, they may be regarded as sequestra.

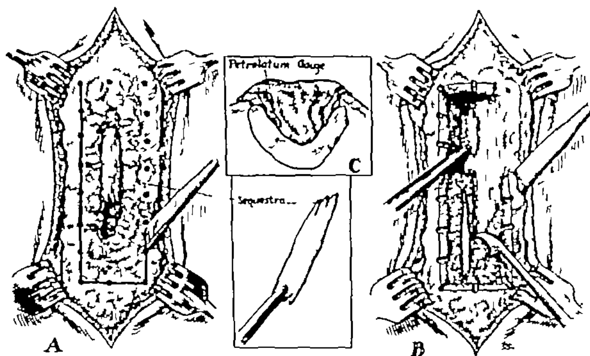


Fig. 793.—Sequestrectomy and curettage. A, Area of cortex to be removed is outlined with drill to prevent pathologic fracture when trap door in cortex is resected with chisel. B, Sequestra and chronic inflammatory tissue removed with curette, bone partially saucerized. C, Cross section of tibia, showing amount of bone removed and method of packing with petrolatum gauze.

Technic.—The tissues over the infected area are incised longitudinally to permit access to as many sinuses as possible; if necessary, the incision may extend the entire length of the diaphysis. The periosteum, which is thick, indurated, and well outlined over the affected bone, is opened throughout the length of the incision and elevated one-half to one inch on each side. In the irregular surface of new bone a trap door is outlined by several holes made with a No. 19 motor drill. The door is then resected with an osteotome. The drilling of multiple holes facilitates accurate removal of the desired amount of bone and reduces trauma and consequent danger of a pathologic fracture during the procedure.

After resection of the trap door, all sequestra are removed and the pyogenic exudate and detritus are curetted from the medullary canal. Should small sinuses connect the area of a large sequestrum to the surface, the sinuses should be excised, if possible; otherwise, they should be curetted. Not infrequently the involucrum itself will contain cavities filled with purulent material and detritus, necessitating eradication by curettage. Following re-

moval of all suspicious material the overhanging edges of the bone are carefully excised. This serves two purposes: to maintain drainage and to allow the wound to granulate from the depths. If possible, sufficient bone should be left to permit subsequent function and weight bearing. Should there be any possibility that a portion of the sequestrum or an additional cavity in the bone has been overlooked, *roentgenograms should be taken in the operating room*, under sterile conditions. In the event sequestra or bone cavities are found they are likewise removed or curetted as necessary. If the sequestra are relatively small, the infection is low grade and drainage is slight, one may be able to remove the sequestra and close the wound primarily, provided adequate antibiotic treatment is given. Otherwise, the wound is packed loosely with petrolatum gauze and a dry dressing applied.

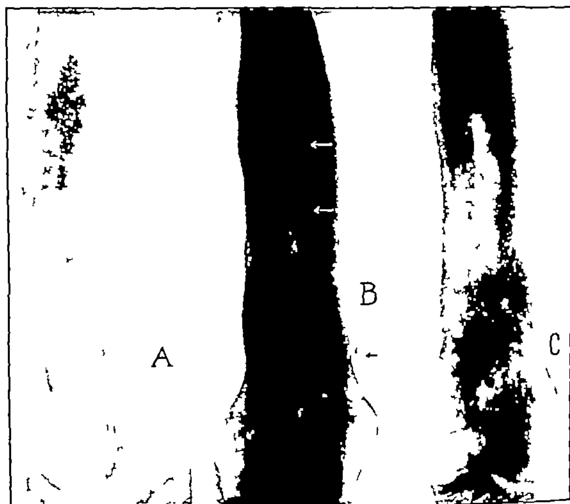


Fig. 799.—*A*, Chronic osteomyelitis of femur with large sequestra posteriorly. *B*, Operating room roentgenogram following sequestrectomy; note remaining sequestra after apparently thorough operative procedure. *C*, Second operating room roentgenogram after removal of sequestra.

After Treatment.—The extremity is immobilized in a plaster cast and a window is cut over the wound to allow changes of the outside dressings. The petrolatum pack is left intact for three to six weeks unless the patient's temperature rises to an excessive degree or pain becomes severe. The cast may then be changed and the wound dressed and packed again with petrolatum gauze. Support of some type should be retained until healing is complete.

this treatment may permit closure of the wound as discussed under 'Chronic Osteomyelitis' (p 1132) Preferably, only the skin and superficial fascia should be closed thus, if the patient does not progress satisfactorily under antibiotic therapy the wound may be reopened and drainage established.

Brodie's Abscess

A Brodie's abscess is a localized form of osteomyelitis which usually develops in the metaphysis of a long bone. Either the organism is of low virulence, or the resistance of the individual is sufficiently high to attenuate the bacteria and wall off the infection

In the treatment of Brodie's abscess, antibiotics should be given for at least twenty four to forty-eight hours before operation. The abscess is then opened, *the lining is curetted, and the overhanging margins of bone are removed* In some cases, the wound may be closed If the cavity contains a considerable quantity of purulent material and the symptoms and laboratory findings justify the assumption of a severe or moderately severe infection the cavity should be loosely filled with petrolatum gauze to establish free external drainage. After the patient has materially improved and the laboratory and clinical findings indicate that the infection has practically subsided, a secondary closure or a skin graft over the wound may be attempted (p 1147)

OSTEOMYELITIS OF SPECIAL REGIONS

OS CALCIS

Osteomyelitis of the os calcis deserves special consideration because of the relative inaccessibility of the bone. By the usual medial or lateral approaches, resection of the diseased area is not readily accomplished. The approach and procedure devised by Gaenslen have added materially to the success of treatment of osteomyelitis of the os calcis. This operation was not designed for the acute stage of the disease wherein the treatment should consist of only medial and lateral incisions for drainage of the soft tissues. Rather it is appropriate for extensive subacute and chronic osteomyelitis

Technic (Gaenslen).—The patient is placed in the prone position and the heel is incised in the midline from the attachment of the tendo achillis to the anterior extremity of the os calcis on the plantar surface. The structures are dissected to the bone the plantar artery vein, and nerve being avoided in the distal end of the wound. With a broad osteotome, the os calcis is divided in half, proceeding obliquely from the posterior and plantar surfaces. The two halves are retracted, exposing the interior of the bone. All sequestra and obviously infected material are removed by curettage, the cortex being left as intact as possible Soft tissue sinuses over the medial or lateral aspect of the heel are likewise curetted or the granulation tissue may be removed by the passage of a dry sponge back and forth through the sinus The wound is loosely packed open with petrolatum gauze

After Treatment.—A boot cast is applied and a window is cut over the os calcis to permit the application of dressings.

As a rule plantar scars are painful on weight bearing this, however is not true following the Gaenslen incision *After healing is complete, the scar is so deeply situated that the edges of the incision curl inward, forming a* thick cushion on each side.

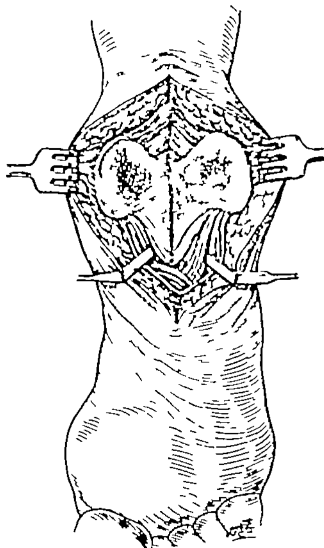


Fig. 300.—Gaenslen split heel incision. Note relation of distal end of incision to plantar artery and nerve. (Redrawn from Gaenslen, F. J.: J. Bone & Joint Surg. 13: 759, 1931.)

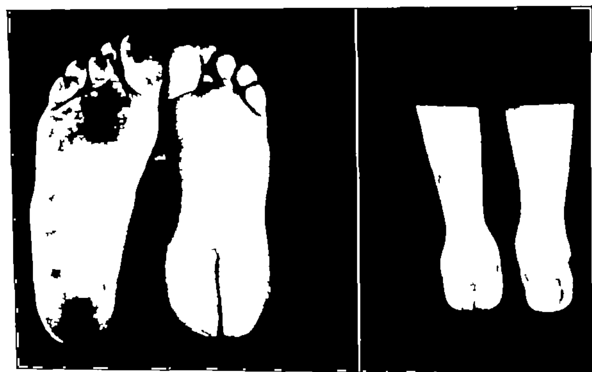


Fig. 301.—Retraction of scar prevents pain on weight-bearing after complete healing of Gaenslen split-heel incision.

LOWER THIRD OF FEMUR

The treatment of osteomyelitis of the lower third of the femur is particularly difficult despite the most effective measures, both surgical and conservative healing may not take place In fact, at no location in the long bones is the problem so intricate. Because of complete separation of the periosteum by subperiosteal abscesses on the posterior surface, this portion of the bone is deprived of the majority of its blood supply and, as a consequence, sinuses frequently persist A mass of scar tissue forms, materially impeding revascularization of the area. The scar tissue moreover is relatively inaccessible because of the close proximity of large vessels and nerves. By changing the patient s position frequently during the acute stage, the collection of purulent material and stripping of the periosteum may be reduced

Technic.—A lateral incision is made in the lower third of the thigh beginning two inches above the articular surface of the femur and extending proximally four inches. The iliotibial band is incised, the vastus lateralis muscle retracted anteriorly and the femur exposed the knee joint at the lower extremity of the incision must not be invaded The operation on the bone should be confined to the lateral and posterolateral surfaces, otherwise, the suprapatellar pouch may be incised leading to a disastrous infection of the joint

By means of drill holes, a trap door is outlined on the lateral surface of the femur and removed exposing the medullary cavity proximal to the metaphysis. In cancellous tissue one should not curette out large areas of normal bone merely because purulent material is exuding from all parts large cavities produced in this manner may never heal. Only necrotic bone is removed The wound is packed loosely with petrolatum gauze from the medullary cavity to the surface

ILIUM

Acute Stage

In the acute stage of osteomyelitis of the ilium the bone is, as a rule, invaded throughout large subperiosteal abscesses being present on both the inner and outer tables Incision and drainage should be preceded by appropriate constitutional therapy particularly blood transfusions and antibiotics, and an ample quantity of blood should be available for transfusions during the operation *The anatomy of this region imposes a definite limitation on the efficiency* of the drainage

Technic.—The incision is begun along the middle third of the crest of the ilium and extended in either direction, according to the location of the largest accumulation of material *If* there is any doubt of establishing adequate drainage the incision may be prolonged the complete length of the crest, thus fully exposing the infected area. The muscular attachments to the outer table are stripped subperiosteally beginning at the anterior superior spine. Generally the purulent material escapes immediately under pressure. In the majority of cases, *the muscles, with the exception of the attachments* to the crest, have already been stripped from the wing of the ilium by the subperiosteal accumulation of exudate. The dissection is then usually carried to the inner table of the wing and the attachments to the crest are stripped away revealing another large subperiosteal abscess. If the incision extends



Fig 802.—*A* Old chronic osteomyelitis of wing of ilium localized to area adjacent to sacroiliac joint. *B* Treated by excision of pathologic bone.

over the middle third of the crest a tube or strip of petrolatum gauze may be inserted between the stripped periosteum and the ilium on both the inner and outer tables well around the posterior and anterior portions of the wing

After Treatment.—Since the hip is usually contracted from spasticity of the iliacus muscle, a Buck's extension is applied to the extremity Drainage will be encouraged if the patient is turned on the affected side at frequent intervals.

Chronic Stage

The extent of the process is determined by the roentgenogram usually the entire ilium is involved as evidenced by mottled areas of destruction, indicating innumerable cavities. The process is so diffuse that removal of all small sequestra and the cleansing of all cavities may be impossible.

If the area has not been opened for drainage during the acute stage, an incision is made along the crest of the ilium as described above, exposing the inner and outer tables. Frequently, exposure of the entire ilium may be necessary All accessible necrotic material and sequestra are removed and the cavities curetted. The wound is loosely packed with petrolatum gauze covering both sides of the ilium.

(Also see "Excision of the ilium, ' p 1145)

SPINE

In the spine, osteomyelitis usually affects the bodies of the lumbar vertebrae, and is therefore practically inaccessible. During the first few days of the acute stage, in addition to extensive antibiotic therapy supportive measures, including blood transfusions and parenteral fluids, are carried out.

Surgical treatment consists principally of efficient drainage of the abscesses after they have penetrated along the fascial planes and intermuscular septa sufficiently close to the surface to preclude danger to important structures. The patient should remain in bed on a Bradford frame during this period, so that compression of the vertebral body may be reduced to a minimum. Abscesses usually point toward the paravertebral area, are *localized* in Petit s triangle, or follow the course of the iliopsoas muscle to form a psoas abscess. The drainage of these areas has been described in the sections on Acute Infectious Arthritis and Complications of Tuberculosis.

After Treatment.—Following evacuation of the abscess the wound is packed lightly with petrolatum gauze to maintain drainage Antibiotic therapy is continued as a further precaution against sequestration. Once formed, sequestra can seldom be removed and drainage may persist indefinitely

Fusion operations for fixation of the spine in the affected area are never necessary in pyogenic infections. The reaction of the bone and soft tissues to the infection is sufficient to produce adequate fixation

MANDIBLE

So far as possible, conservative measures are advisable in the treatment of osteomyelitis of the mandible. During the acute stage, treatment consists of drainage of soft tissue abscesses only the less one interferes with the bone at this time, the better the end result. Radical treatment, moreover is frequently disastrous to the appearance of the face. Extraction of the teeth is unwarranted unless they are loose or are in the immediate vicinity of a pathologic fracture of the infected mandible.



Fig. 802.—*A* Old osteomyelitis of entire mandible. No surgical treatment other than thorough drainage for seventeen months, and removal of small superficial sequestra. Entire right half of mandible (a sequestrum) except condyle, resected subperiosteally leaving small amount of involucrum. Thorough curettage and sequestrectomy of left side of mandible. *B* Regeneration of mandible, with restoration of continuity of bone, preserving contour of face and forming satisfactory base for dental prosthesis.

Roentgenograms should be made at frequent intervals to determine the response of the periosteum to the infection and the line of demarcation between living and dead bone Removal of sequestra is not undertaken until roentgenograms show that sufficient involucrum has formed to maintain function and preserve at least an almost normal contour of the jaw This may require from six months to one year meanwhile aside from the additional drainage caused by the sequestra their presence will have no deleterious effect.

Technic.—The incision for removal of sequestra should conform to the normal contour of the under surface of the mandible over the affected region, the soft tissue being disturbed as little as possible. Obviously diseased tissue and sequestra are removed but no attempt is made to curette the entire area involved. Drainage is maintained by a petrolatum wick. This procedure prevents unsightly readily visible scars and asymmetry of the face.

MASSIVE EXCISION IN OSTEOMYELITIS

This measure was first advocated by Nichols and was employed for osteomyelitis of all long bones. Although undoubtedly some brilliant and rapid cures have been effected by excision of the long bones, gross deformities bordering on disasters are produced so often particularly when the member is dependent upon the one bone for support, as in the thigh and upper arm, that the procedure should be limited almost exclusively to the metatarsal and tarsal bones, the fibula, ilium ribs, and occasionally the clavicle or scapula, or a portion of these bones. In children under five years of age, although subperiosteal resection of a long bone may be followed by reformation of the shaft, this radical procedure is absolutely unwarranted, as excellent results may be secured by more conservative operative treatment. Failure of the periosteum to reproduce the entire shaft causes a serious disability similar to those of congenital absence or defects of these bones, which is difficult to repair the quality of the bone is unsatisfactory for bone plastic procedure and relighting of a dormant infection is common. The technic for restoration of continuity is described in Chapter X.

EXCISION OF THE METATARSAL BONES

Since the first metatarsal bone plays an important part in weight-bearing complete excision of this bone is rarely advisable. When the second, third, fourth or fifth metatarsal bones are involved, however particularly in young children, a subperiosteal resection may be followed by formation of new bone which partially or entirely replaces the one excised.

Technic.—A longitudinal incision is made over the affected bone parallel with its long axis, from the distal row of tarsal bones to the middle of the first phalanx The soft structures are divided the tendon sheaths being preserved intact. The periosteum is incised in line with the shaft and completely stripped from the circumference of the bone, and the entire bone is resected from metaphysis to metaphysis. In children, the epiphyses should remain undisturbed A small drainage tube is inserted and allowed to protrude from the distal end of the wound. The periosteum is sutured over the tube.

After Treatment.—The foot is placed in a splint or cast. At the end of one week, if drainage is not profuse, the tube is removed and the wound allowed to heal.



Fig 804 —Defect of shaft of humerus following excision; restoration of continuity of bone by transplantation of fibula.

EXCISION OF THE TARSAL BONES

In acute osteomyelitis or purulent osteochondritis of the tarsal bones, the principles of incision and drainage are similar to those observed in the long bones. Frequently more than one bone is involved by direct extension of the infection. After a thorough trial of less radical measures, excision of the involved tarsal bones, with the exception of the os calcis, may be undertaken. The technic is described in the section on Excision for Tuberculosis (p 909)

EXCISION OF THE FIBULA

Rountree has shown that the upper three-fourths of the fibula may be excised without fear of impairing function even though the shaft is not reformed. The lower one-fourth of the shaft, however should not be excised, as the subsequent deformity at the ankle joint will materially interfere with use of the member The acute symptoms of the disease should be allowed to subside before resection is carried out.



Fig. 805.—*A*, Chronic osteomyelitis of shaft of fibula. *B* After resection of upper two-thirds of fibula. Six months postoperatively there is little regeneration of bone, despite careful subperiosteal resection. Function of extremity not impaired.

Technic.—An incision is made on the posterolateral surface of the leg from the head of the fibula to the lower one half or one fourth, depending upon the amount of bone to be resected. The peroneal nerve should be identified and

retracted (p 172), and the fibula exposed as described in Chapter IV Beginning just distal to the upper fibular epiphysis, the periosteum is incised in line with the bone and stripped from the entire circumference The diseased portion of the shaft including, if necessary, the upper two thirds is excised A soft rubber tube is placed in the periosteal sheath and the upper three fourths of the wound is closed the tube being allowed to protrude from the lower portion of the wound

After Treatment.—A long posterior night splint is applied and the wound is dressed every two or three days. The soft rubber drainage tube is withdrawn approximately one inch or one and one half inches at each dressing until removed in its entirety

EXCISION OF THE WING OF THE ILIUM

In osteomyelitis of the ilium with prolonged drainage or acute exacerbations of the infection which are not relieved by the measures described above excision of a large portion of the bone may be necessary A number of surgeons advise this procedure routinely when the infection is extensive Such treatment, however should be reserved for the chronic stage of the disease after all less radical methods have been tried and proved ineffectual. Following excision, partial reformation of the ilium may take place



Fig. 406.—Subperiosteal exposure for resection of wing of ilium. Poupart's ligaments can be reflected from the ilium, permitting removal of bone from superior ramus of pubis to sacroiliac joint. (From Badgley C. E. Arch. Surg 28 83 1934.)

Technic (Badgley).—The incision is begun on the posterior superior spine of the ilium just below the crest carried to the anterior spine, thence onto the thigh parallel to the sartorius muscle. The fascia is divided one-half inch below the crest, and the periosteum is incised in the line of the skin incision along the crest. With a periosteal elevator the gluteal muscles are detached subperiosteally down to the acetabular rim. The interval between the tensor fasciae femoris and the sartorius muscles is developed and the gluteal muscles are retracted bringing into view the anterior portion of the ilium. In children the cartilaginous crest of the ilium may be easily detached while the insertions of the abdominal muscles remain in situ. Von Bergmann recommended that in adults the crest be chiseled off to maintain these attachments. Badgley has found it simpler and equally effective to continue the subperiosteal dissection over the crest of the ilium detaching the abdominal muscles, the latissimus dorsi the quadratus lumborum, and the erector spinae muscles at their insertions. When this has been accomplished, the abdominal contents fall away giving excellent exposure of the wing. The muscles on the inner table of the ilium are next stripped subperiosteally to the arcuate line. By means of a motor saw or osteotome one may then remove the ilium en masse to the supracotyloid region or if necessary back to the sacroiliac joint.

After Treatment.—The posterior two-thirds of the wound may be closed. The remaining portion is packed with petrolatum gauze to provide drainage for the entire area.

EXCISION OF THE RIBS

In the acute stage of osteomyelitis of a rib the periosteum is usually distended by a subperiosteal accumulation of pus. Drainage is effected by incision into the periosteum over the diseased area. If sinuses persist after the acute symptoms have subsided complete excision of the involved portion of the rib results in a permanent cure in a large number of patients.

Technic.—Through an incision parallel to the affected rib the periosteum is stripped from the circumference of the rib to normal bone on both sides of the lesion. A blunt periosteal elevator is placed beneath the rib between the periosteum and pleura and the rib is severed by a Gigli saw. Care must be exercised to avoid penetrating the pleura. A tube is inserted from the most dependent portion of the wound and covered over by the periosteum and skin. The tube is removed after one week.

PATHOLOGIC FRACTURES ASSOCIATED WITH OSTEOMYELITIS

In many cases, because of lack of involucrum, pathologic fractures of the shafts of the long bones occur during the acute or subacute stage before the patient is observed or as the process continues, the bone becomes hard dense, and brittle and fracture may take place at operation if too much force is exerted with a chisel and mallet or an excessive amount of bone is removed.

Regardless of how a fracture may have occurred, operative procedures for osteomyelitis should be carried out thoroughly and the fragments then approximated in good alignment and immobilized as for any other fracture. A window of sufficient size to permit dressing of the wound is cut in the cast. Since the cast softens from soiling by the purulent exudate, reinforcements should be applied to provide additional strength.

Union of sclerotic bone of this type is usually delayed As the infection subsides, however union usually takes place unless an excessive amount of bone has been removed in previous treatment

OSTEOMYELITIS FOLLOWING GUNSHOT WOUNDS AND COMPOUND FRACTURES

One of the outstanding advances made in surgery during the World War II was in the treatment of osteomyelitis following compound fractures and gunshot wounds. Formerly, the infection persisted over a period of months or years with the technics developed during the war, the majority of cases may now be brought under control within a relatively short time

These patients present a chronically draining wound with more or less extensive loss of bone Frequently, a considerable area of skin has been destroyed resulting in scar formation Severely debilitated patients who have had infected wounds over a long period of time should receive preoperative care directed toward their general physical improvement This should include a high protein diet multiple blood transfusions and antibiotics.

A surgical program consisting of three stages, as outlined by Knight and Wood has proved satisfactory (1) Complete sequestrectomy (2) application of a split skin graft as a dressing for the defect and finally (3) bone grafting and covering of the wound with a pedicle skin flap

First Stage Sequestrectomy and Saucerization of the Cavity.—Scar tissue involving the region is excised as completely as possible and all dead bone sequestra, and foreign bodies are removed No bone should be removed unnecessarily at the same time extreme care must be taken to excise all infected bone, as well as any granulation tissue remaining in the interstices of the bone If possible union should be preserved in some cases, however the creation of defects in the bone will be unavoidable Frequently a dense sclerotic type of bone will be found should one be in doubt as to its viability this should also be removed All overhanging ledges should be trimmed away and the wound saucerized and planned for the next stage The wound is packed open with petrolatum gauze and if necessary because of fracture and loss of osseous tissue plaster immobilization should be provided

The wound is inspected after eight or ten days Knight and Wood suggest observation as early as five to seven days. After ten days to three weeks, the area is usually covered with a good growth of granulation tissue and is ready for a thin split skin graft

Second Stage Application of the Skin Graft.—The extremity is prepared aseptically and a split skin graft from 0 010 to 0 015 inch thick (usually about 0 012) is elevated with the Padget dermatome At this point, some surgeons prefer to remove the granulations by curettage and suture the graft edges to the skin One may however simply place the graft on the fresh granulations allowing the edges to project onto the normal skin. The graft is pressed into the defect by carefully applied pledgets of mechanics' waste and a pressure dressing is applied This method has been successful in our practice

The patient is given penicillin for three days after the operation. The wound is dressed at six to ten days In a large number of cases the graft takes completely thereby providing a continuity of skin from a healed non draining area over a previously septic wound Following thorough healing

of the skin graft, and provided the infection remains quiescent for a reasonable length of time (usually three to six months) the next stage of the program may be considered.

Third Stage Bone Grafting and Covering of the Wound With a Pedicle Skin Flap.—The type of bone graft used depends upon the requirements of each case a large defect will require a massive graft, whereas a relatively small defect may be filled with cancellous chips from the ilium. The split skin graft applied in the second stage is excised and the bone surfaces are prepared for the transplants The skin flaps should be in readiness for use before the bone grafting is done.

After completion of the bone-grafting procedure (p 119) the skin defects may be closed without tension by one of three methods First, by under cutting and approximating the skin second by making so-called relaxing incisions " or by elevating double pedicle flaps at the level of the skin defect on one or both sides and third if loss of skin is extensive by the use of free transplants to cover the defects. External fixation is applied following operation, usually by a plaster cast. Penicillin therapy is begun two days preoperatively and continued for ten days after operation.

SCLEROSING OSTEOMYELITIS OF GARRÉ (LOW GRADE OSTEOMYELITIS)

The following is a quotation of the first paragraph on this subject as published in the first edition of this book

' Sclerosing osteomyelitis of Garré is characterized by a pronounced increase in density of the bone. This condition is most often observed in the tibia and femur The entire shaft may be involved and some portion of the shaft, usually the middle and lower thirds, may be enlarged. The exact etiology is unknown but is thought to be a subacute infectious process cultures from the bone, however give negative findings. Roentgen ray therapy has been employed for this condition, but in the author s experience, has proved valueless. Operative treatment is not always successful, as pain may persist in definitely despite radical measures.

The exact etiology of osteomyelitis of Garré is still unknown, though we now know that, in some cases, findings consistent with osteomyelitis of Garré are produced by osteoid osteomas involving the cortex of the shafts of the long bones. It is also known that drilling of multiple holes in the sclerotic bone to open the medullary canal as formerly employed, relieved the pain of some patients but not of others. Removal of a section of cortical bone, as in taking a bone graft, had a similar effect From a review of a number of our old cases, it appears that this may be explained by the fact that an osteoid osteoma was present in some cases the nidus was removed, thus relieving the patient of his pain whereas in other cases the removed portion of the cortical bone did not contain the nidus and the pain persisted.

In the event the picture of osteomyelitis of Garré cannot be attributed to an osteoid osteoma, the etiology must be sought elsewhere. Probably this condition also arises from a low grade infection of the bone which is not sufficiently severe to cause suppuration or constitutional symptoms similar to those usually exhibited by ordinary acute pyogenic osteomyelitis.



Fig 607.—*A* Clinical diagnosis osteomyelitis of Garré. Months later specimen resurrected and re-examined Roentgenc scopic sections showed characteristic findings of osteoid-osteoma

All patients with the findings of osteomyelitis of Garré should have roentgenograms of the bone in multiple planes and with varying intensities of exposure to determine, if possible whether or not a nidus is present. The discovery of a nidus will lead one to make a tentative diagnosis of osteoid osteoma. Should this be true, the cortical bone in the involved area should be removed and multiple roentgenograms of varying densities again made. If a nidus is again definitely demonstrated sections should be taken from the area for microscopic study. Only by this means will the diagnosis of osteoid osteoma be established or ruled out (see also p 1175)

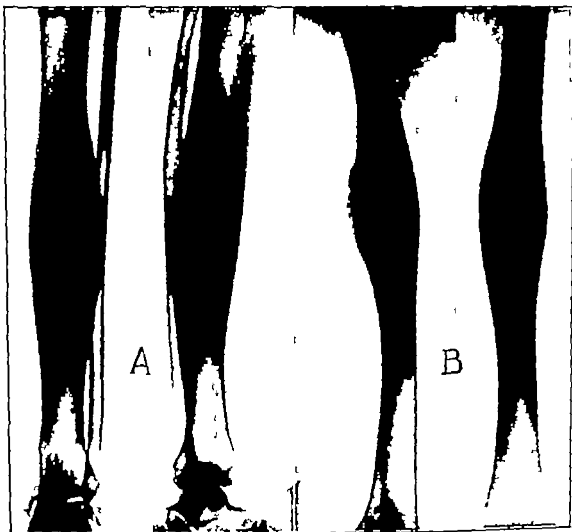


Fig. 801.—Sclerosing osteomyelitis of Garré. A Tibia. B Femur. Treated by drilling multiple holes with relief

TUBERCULOSIS OF THE SHAFTS OF BONES

Tuberculosis of the shaft of a bone is relatively rare in this country. Frequently the infection is associated with active pulmonary tuberculosis. The process may be diffuse, involving the entire shaft, or localized to one area often juxta-articular. As a rule, the roentgenogram demonstrates a solitary irregular cavity or as the disease progresses, a succession of confluent cavities. Occasionally a fusiform enlargement of the shaft closely resembling the osteomyelitis of Garré, may be apparent.

The treatment of tuberculosis of the shaft of a bone is essentially identical to that of chronic infectious osteomyelitis, in tuberculosis however all wounds may be closed unless draining sinuses or secondary pyogenic infection is present prior to operation Basom found that healing most often followed exploration and drainage Further in tuberculosis, an aseptic technic should be rigidly enforced The examination of a pathologic specimen macroscopically and microscopically demonstrates the characteristics of tuberculosis

Hodges, in reviewing the cases of tuberculosis of the long bones at the clinic found that biopsy, bacteriologic and histologic studies were usually necessary to distinguish the disease from the various other infections with which it might be confused In addition he observed that tuberculosis of the long bones was often multiple and associated with other tuberculous lesions and that the majority of such patients were so acutely ill that no operative treatment was indicated

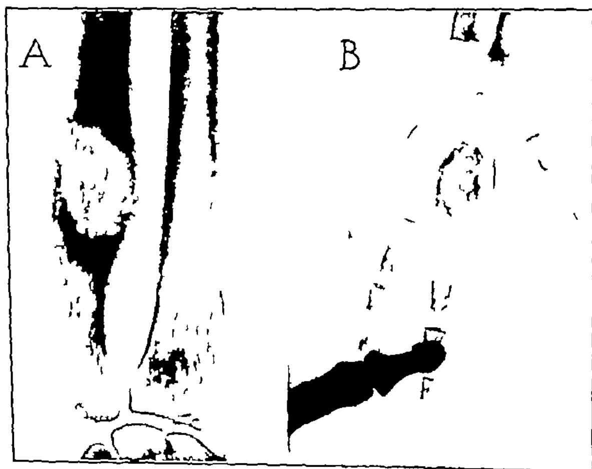


Fig. 809 —Tuberculosis of long bones. A Atypical tuberculosis of ulna, proved by biopsy B Typical spina ventosa. This patient had multiple cavities throughout skeleton. First diagnosis, syphilis positive Wassermann. No improvement under antisyphilitic treatment. Biopsy revealed typical tuberculosis. Later developed tuberculous otitis media, and succumbed two years after first examination.

Rarely the process may invade the joint by direct extension. In this event, the treatment should be carried out as for tuberculosis of joints (Chapter XIV)

The prognosis for recovery is good unless the joint is invaded or the infection in the shaft is extensive and associated with active pulmonary tuberculosis. Hsieh Miltner and Chang observed that secondary infections have



Fig. 816.—Monilia infection of cuneiform bones, twenty years' duration. Before and after resection and arthrodesis.

a favorable influence upon the healing of tuberculous lesions of the shafts of bones. They regarded this as being brought about by an increased fibroblastic reaction of the soft tissues

FUNGUS OR YEAST INFECTIONS

As a rule yeast or fungus infections of bone such as blastomycosis, actinomycosis, or moniliasis, are best treated by iodides and roentgen ray therapy



Fig. 411.—Same as Fig. 410 All wounds healed seven months postoperatively. Satisfactory weight-bearing foot, with sufficient residual motion in tarsal joints for normal gait.

Surgical measures consist principally of complete excision of the pathologic bone. *Unfortunately* however fungus infections frequently involve bones wherein excision is impracticable or impossible such as the mandible or spine. Excision, if feasible, is carried out as described for tuberculosis.

In a few cases of monilia infection of the tarsal bones, the results following incision were even more satisfactory than for tuberculosis.

Coccidioidal Osteomyelitis

Coccidioidal osteomyelitis is an affection of the bones caused by the fungus *Coccidioides immitis* The disease is relatively rare, having a geographical distribution practically limited to California, and in particular to the San Joaquin Valley

Characteristic of this infection *according to McMaster and Gilfillan*, is a multiplicity of foci. Combined pulmonary and osseous lesions are most commonly observed and carry a grave prognosis. Lesions of the bones and joints are regarded as secondary to a primary infection at the portal of entry, although such an active primary focus may not be demonstrable. The osseous lesions usually develop in cancellous bone in the regions of the joints, particularly the bony prominences about the joints not infrequently however the process is primarily localized in the synovial membrane. In either case, the articular cartilage and cortex may be invaded by direct extension, leading to ankylosis.

Both acute and chronic forms of coccidioidal osteomyelitis are observed. Necrosis, abscess, and osteoclastic destruction are features of the acute bone lesions. The chronic forms generally present coccidioidal granulation tissue or abscesses. Microscopic sections of the tissue reveal a decided similarity to tuberculosis. Coccidioidal spores may be found either loose in the stroma or embedded in Langhans giant cells.

McMaster and Gilfillan report twenty four cases and describe the treatment as follows In combined pulmonary and bone lesions, general supportive treatment is carried out, as well as immobilization of the involved bones and joints, to prevent metastatic spread of the disease. As a rule, conservative measures are preferable in cases of acute or severe general infection. In *chronic infections*, the treatment is similar to that for chronic osteomyelitis, i.e., drainage is instituted and the bone is saucerized. If the lesion is confined to the joints, treatment is carried out as for tuberculosis of joints, as healing is unlikely until the joint is completely ankylosed. Since the mortality is high and multiple foci may form the procedure of choice for single peripheral lesions of the extremities is amputation.

SYPHILIS OF BONES

Syphilis of bones per se seldom requires surgical intervention, as intensive antisyphilitic therapy usually suffices. Sequestra *may be present*, but the process develops gradually and the bone does not undergo necrosis en masse. Occasionally an associated pyogenic infection necessitates treatment as described for infectious osteomyelitis.

OSTEITIS FIBROSA CYSTICA

(Diffuse and Local)

These are two entirely separate clinical entities, although the appearance in the roentgenogram may be identical In generalized osteitis fibrosa cystica the bone cysts are the result of an adenoma and *hyperactivity of the para* thyroid gland, and a consequent calcium imbalance which causes the calcium to be withdrawn from the bones. Aside from reduction of associated pathologic fractures or the prevention of deformity from crushing or compression

of the vertebrae, patients with this condition should be referred to the roentgenologist for roentgen ray therapy or to the general surgeon for removal of the parathyroid tumor

Localized osteitis fibrosa cystica is of a different origin, and perhaps should be known by another name Geschickter and Copeland believe that many solitary cysts are the reparative or end stage of giant cell tumors. Undoubtedly a number of these lesions subside spontaneously while others are cured by roentgen ray therapy In every case the process should be kept under close observation and if sufficiently extensive to invite fracture on slight trauma operation is advisable If the first sign is a pathologic fracture operation may be postponed as the trauma of the fracture may so stimulate bone production that a cure will be effected without surgery If the cyst is sufficiently large to permit a pathologic fracture however a spontaneous cure is unlikely and operation will usually be necessary Since these local cysts are commonly observed in the upper end of the femur the operation will be described for this region as an example of the technic to be followed in other locations.

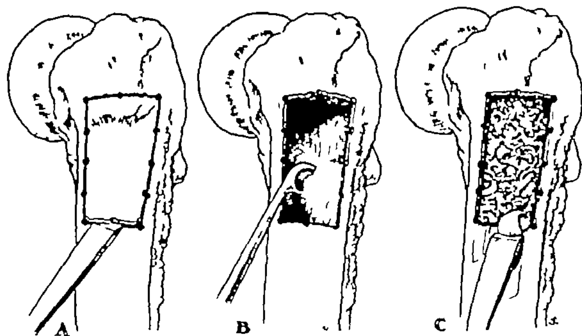


Fig 812.—Operation for osteitis fibrosa cystica. *A*, Trap door outlined by drilling of holes removed with chisel. *B* Lining of cavity removed with curet. *C* Cavity filled with bone chips from adjacent area or from tibia.

Technic.—The upper two inches of the shaft of the femur the anterior surface of the trochanter and the lateral portion of the neck of the femur are exposed by a curved lateral incision (p 150) between the gluteus medius and tensor fasciae femoris muscles The vastus lateralis muscle and the periosteum are stripped from their upper attachments to the femur exposing the anterior and lateral surfaces of the shaft With a No 19 drill several holes are now made into the cavity and the entire roof is excised with an osteotome or rongeur forceps. All fluid and fibrous tissue lining are removed and the osseous wall is scraped with a curet to remove the superficial scale of bone The chips from the roof are now denuded of fibrous tissue and placed in a sterile pan. Shavings are removed from the shaft of the femur below and placed within the cavity together with the bone chips from the roof A sufficient



Fig. 813.—*A* Bone cyst of upper third of humerus. *B* Four years postoperatively normal humerus with no evidence of former cyst.

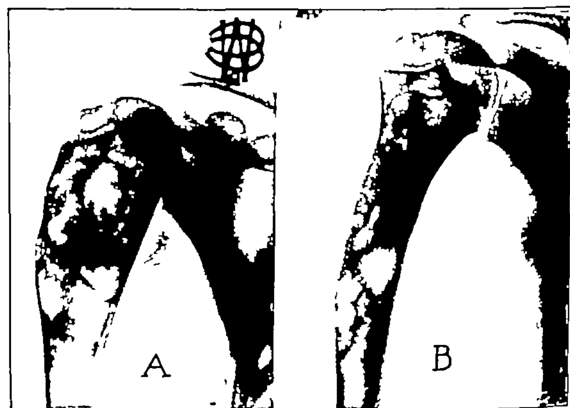


Fig. 814.—*A* Multilocular cystic destruction of upper end of humerus. Treated by curettage and filling of cavity with bone chips. *B* Partial healing of cystic process of upper third of humerus, but extension of destruction distally on shaft. After failure of conservative surgery this type of affection might preferably be treated by resection and substitution by a graft, as suggested by Inclan.

quantity of bone should be inserted into the cavity to induce osteogenesis on being mixed with a blood clot This necessitates filling the entire cavity loosely with bone chips. The required amount is seldom obtainable from the femur if not additional transplants, including as much cancellous bone as possible should be taken from the ilium It is advisable to remove the bone from the ilium rather than disturb the normal bone adjacent to the cystic area The bone bank has also been a satisfactory source of fillage material The periosteum which has been carefully preserved may be closed tightly without difficulty holding the grafts within the cavity

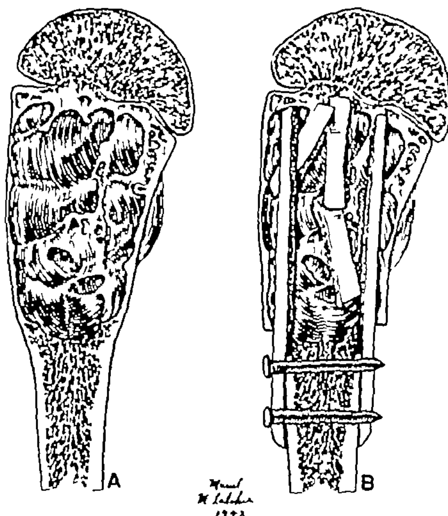


Fig 815—A Bone cyst of upper end of humerus. B Dual graft utilized to reinforce cortices through area of bone cyst. Cavity eradicated by additional grafts. (From Rogers W A. Arch. Surg 46 759 1943.)

Microscopic examination of the excised tissue should always be made Microscopically the cyst may resemble a giant cell tumor In children, there is usually no occasion for confusion of the cyst with a malignant tumor of the bone. In adults, however lesions in the upper end of the femur which resemble bone cysts or giant cell tumors may prove to be malignant

After Treatment.—If the cavity is very large, support of the extremity in a walking caliper splint may be required until bone production is ample to prevent a fracture.

The end results are almost uniformly excellent and recurrence is unusual.

Inclan believes that a localized osteitis fibrosa cystica which progresses from the metaphysis toward the diaphysis, with repeated and multiple frac

tures, should be treated by excision en bloc. He has employed this technic in two lesions of the upper third of the humerus, resecting the bone subperiosteally in order to preserve the muscular attachments. A tibial graft is then utilized to form a bridge between the head of the humerus and the remainder of the diaphysis, the periosteum being sutured about the graft. Rapid regeneration followed this procedure, the humeral diaphysis reforming within eight weeks and forty five days, respectively in the two cases.

In our experience, such a radical procedure has been unnecessary in the treatment of bone cysts.



Fig. 816.—Postoperative roentgenogram of bone cyst treated by dual bone grafts. Cyst eradicated at end of eight months. (From Rogers, W A. Arch. Surg. 48 709 1944.)

Rogers has suggested a unique method of utilizing a dual cortical graft to reinforce the thin walls of a benign cyst. In the two cases which he reported, the grafts were used for expansile, thin walled cysts in the upper humeral metaphysis. By *the procedure, mechanical fixation is adequate, and* the grafts provide the necessary osteogenic factors to eradicate the cysts.

Technic (Rogers) —After exposure of the cyst, a longitudinal slot is created in the anterior cortex through this opening the lining membrane is curetted and removed Two transverse slots are made on each side of the bone in the wall of the cyst at its junction with the shaft. Two full thickness cortical grafts from the tibia one centimeter wide and three centimeters longer than the cavity are inserted through the slots into the interior of the cyst. These grafts should not violate the adjacent epiphyseal plate. The ends

of the grafts are fastened snugly to the shaft by two transfixion screws in the manner of dual onlay grafts. The residual defect in the cyst cavity is eradicated by multiple cancellous bone grafts

RICKETS

Since the discovery of vitamin D deficiency as the causative agent of rickets, operative treatment has been required in a much smaller number of cases. Further, patients are now observed during the early stage of the deformity Those under four years of age may be treated successfully by conservative measures.

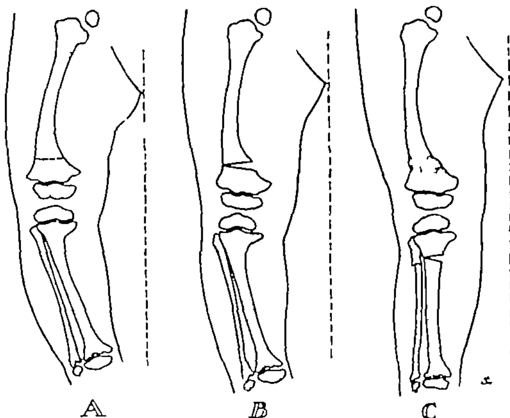


Fig. 817 —Operation for genu varum (bowlegs) *A*, Dotted line indicates osteotomy site. *B*, After correction of deformity defect fills with callus. *C*, Varus deformity of upper third of tibia. Correction completed by osteotomy through condyles and manual fracture of fibula. (Deformity of tibia usually corrected first. This may suffice.)

Surgery is undertaken in rickets only for the correction of residual deformity after the process has entirely subsided Prior to this time, operative treatment is followed by recurrence. Moreover operation should not be undertaken until the child is four years of age and the roentgenographic and clinical examinations indicate that the epiphyses have attained their normal structure. In active rickets, the epiphyses are increased in width and are more irregular than normal. The discs are much smaller than the metaphyses, which are flared at the epiphyseal line. When the process subsides the discs become of the same dimensions as the metaphyses. At this time, operations for correction of deformity are indicated

The deformities which commonly require surgical correction are genu valgum and genu varum or knock knees and bowlegs. Genu valgum affects the femur chiefly while genu varum affects the femur tibia and fibula the bones of the lower leg often being more severely deformed That these de

formities are the result of rickets rather than of congenital origin should be determined before operation. In congenital bowing the quality of the bone is such that nonunion will probably follow osteotomy.

In children, preliminary decalcification of the bones by immobilization of the extremity in a plaster cast for a period of eight weeks may expedite correction of these deformities (Finkelstein). The patient is then given an anesthetic and the bones are manually molded into correct anatomic alignment.

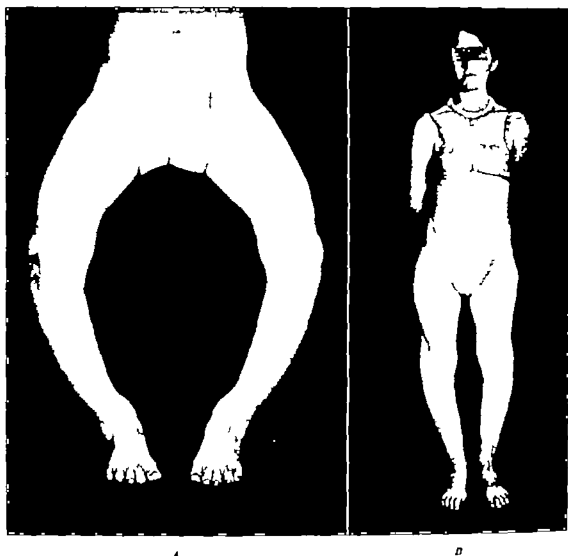


Fig. 812.—A. Extreme varus deformity induced by rickets, corrected by osteotomy of both tibiae and femora. B. Four years postoperatively. Slight deformity still present in right lower extremity but function satisfactory.

Before the development of asepsis, when infection was a serious problem in all bone surgery, genu varum or genu valgum was corrected by means of an osteoclast, an instrument for performing osteotomies without incision. Its use was continued until comparatively recent times, but has now been practically abandoned. The instrument is therefore of only historical interest.

Latent rickets, which is manifested at the age of puberty, may cause similar deformities. These should also be corrected according to the following methods.

GENU VARUM (BOWLEGS)

The deformity of bowlegs is not alone outward bowing but a rotation or inward torsion of the tibia from the knee to the ankle Correction to a satisfactory degree may usually be accomplished by osteotomy at the most convex point of the tibial crest which usually is in the upper third Both legs may be corrected at one operation as the procedure is relatively simple and unattended by surgical shock

Tibia

Technic.—A longitudinal incision one inch in length is made over the internal surface of the tibia at the point of greatest convexity A three fourths inch osteotome is inserted down to the bone, turned at a right angle to the

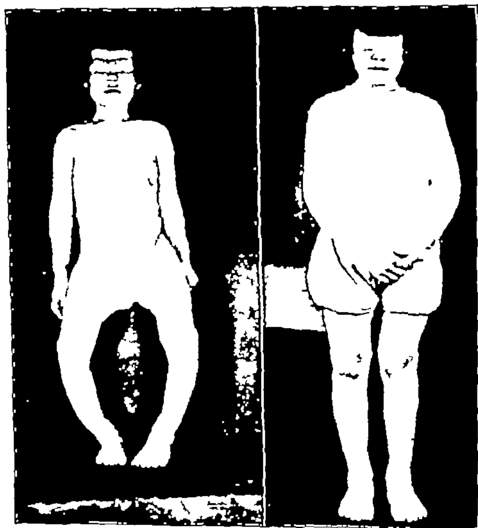


Fig. 819 —Bowlegs incident to rickets. Before and after correction by osteotomy of tibiae.

shaft, and driven transversely through three fourths of its diameter Both the tibia and fibula are then fractured manually For ultimate anatomic alignment, the fragments are approximated in slight overcorrection of the bowing In severe deformities, plastic elongation of the tendo achillis (p 1021) may be required.

After Treatment.—A plaster cast is applied from the toes to the upper third of the thigh holding the knee in extension and slight overcorrection and re-establishing normal relations as to torsion of the tibia When deformity

is severe the knee should be immobilized in flexion. At the end of three weeks, the cast is changed and further correction made if necessary After six weeks, the cast is removed and a bowleg brace and night splint are fitted, to be worn for six months.

Femur

In some cases, correction of the femur also may be necessary This, however should not be attempted until union of the tibia is complete, which requires eight weeks or longer Occasionally the surgical procedure on the femur must be preceded by a period of two or more months of walking with the support of braces. The deformity is corrected in both femora at one operation In children the epiphyses must be avoided

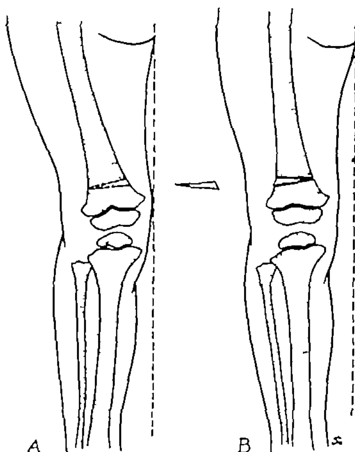


Fig. 820—Operation for genu valgum. Usually supracondylar osteotomy of femur suffices. A Dotted lines indicate wedge-shaped section f bone to be removed. B Wedge of bone reversed and replaced to maintain correction of deformity

Technic.—The femur is approached through a one-inch longitudinal incision two to three inches above the external condyle. An osteotome is inserted and turned at a right angle to the bone, then driven across three-fourths of its diameter The remainder is fractured by manual force and the fragments are approximated in slight overcorrection of the bowing

After Treatment.—A cast is applied from the toes to just above the crest of the ilium. The treatment thereafter is carried out as following correction of the tibial deformity The braces, however must extend to above the crest of the ilium and must have a joint at the hip and a strap about the site of the osteotomy to prevent recurrence of the deformity The end result in uncomplicated cases is excellent

GENU VALGUM (KNOCK KNEE)

Genu valgum in older children and adults is corrected by supracondylar osteotomy on the lateral or medial aspect of the femur The medial subcutaneous osteotomy is more satisfactory as this is the more prominent and more accessible side Not only must the valgus be corrected but the rotation or outward twist of the lower end of the femur as well

Technic.—A small longitudinal incision is made on the medial aspect of the thigh just above *the lower femoral epiphysis and a transverse osteotomy* is performed as described for genu varus.

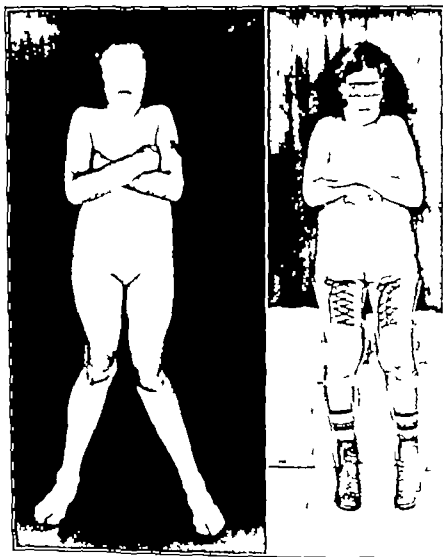


Fig. 821.—Valgus deformity of knees before and after correction by supracondylar osteotomy

After Treatment.—The extremity is placed in the overcorrected position, or varus and a cast is applied from the toes to just above the crest of the ilium

If the deformity is severe and torsion pronounced the following procedure may be required

Technic.—The medial aspect of the lower extremity of the femur is incised a distance of three inches exposing two inches of the bone (p 175) From the anteromedial aspect a wedge is removed, of sufficient dimensions to

allow complete correction of the deformity The wedge is reversed in order to fill the defect produced on the posterolateral aspect by correction

After Treatment.—The limb is immobilized as described following tibial correction. After six weeks, a knock knee brace is applied to which are attached straps to pull the lower extremity of the femur and the leg inward and prevent recurrence.

Milch has emphasized the necessity for correction of deformities about the knee at the site of maximum angulation and for restoring the normal relationship of the articular surfaces of the tibia. Unless these are done, an osteotomy for correction of the genu valgum alone will not be successful. He has also advocated an incomplete osteotomy of the tibia not sufficiently high in the shaft to require osteotomy of the fibula yet sufficiently low to avoid damage to the epiphyseal line. After partial osteotomy of the tibia, the deformity is corrected by producing a greenstick fracture of the undivided portion of the tibia

ANTERIOR BOWLEGS

The so-called saber tibia ' may be caused by rickets or syphilis. The deformity is rarely observed in this country Correction cannot be accomplished satisfactorily by one osteotomy two or three must be carried out at different levels of the bone and at different operations. Contour of the extremity is not restored to normal but is materially improved, permitting normal function See Moore osteotomy-osteoclasis, p 1013

The following procedure although radical, might be utilized in an exceptional case The Haas osteotomy (p 1372) is also applicable.

Technic.—A longitudinal anterolateral incision is made over the entire length of the tibia and carried down through the periosteum. From one-half to two-thirds of the shaft is excised subperiosteally by means of a Gigli saw The bone is then fractured with a chisel and mallet or cut with large bone forceps into small particles, and replaced within the periosteal tube. The fibula is fractured manually

After Treatment.—The extremity is placed in a plaster cast from the toes to the upper third of the thigh holding the knee in flexion and maintaining the normal contour of the bone.

We have never employed this technic, even in young children Because of the probability of nonunion the operation is not suitable for older children and adults. This procedure is definitely not applicable to bowing of congenital origin (p 1578)

COXA VARA

Coxa vara as a result of rickets is corrected by subtrochanteric osteotomy as employed in this deformity from other causes (p 1043)

TIBIA VARA

Tibia vara according to Blount, is "an osteochondrosis similar to coxa plana and Madelung s *deformity* but located at the medial side of the proximal tibial epiphysis. The deformity is characterized by a varus, recurvatum and internal rotation of the leg The affection may appear during the first year or two of life or at adolescence. It is essential that this lesion be differentiated from rickets, since correction during the period of growth is always followed by recurrence nevertheless, successive osteotomies for correction of

the anomaly are warranted to permit more normal growth of the soft parts and prevent severe deformity when full growth is attained. Full correction may then be made with the assurance that recurrence will not take place.

CONGENITAL DEFICIENCIES OF BONE

The following affections of bone apparently of congenital origin are rarely amenable to surgery: osteosclerosis or marble bones, chondrodysplasia, dyschondroplasia, achondroplasia and osteogenesis imperfecta. Although

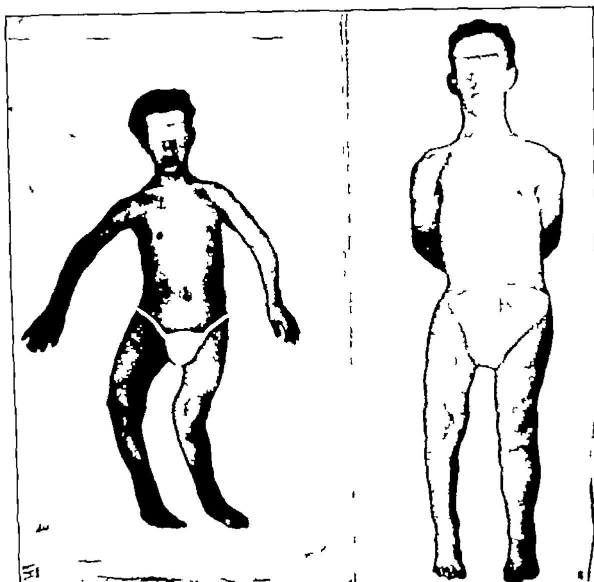


Fig. [illegible].—Genu valgum and genu varum deformity before and after correction by osteotomy. Deformity secondary to chondrodysplasia. Procedures carried out after growth ceased.

deformities associated with dyschondroplasia may be alleviated by operation during the period of growth, there is always a recurrence. In fragilitas ossium the process usually becomes inactive after puberty; thereafter osteotomies, as employed in rickets, and other procedures as described in the chapter on Ankylosis and Deformity may be applicable. The treatment of chondrodysplasia (Ollier's disease or multiple osteochondromata) is described in the chapter on Tumors.

ENDOCRINE DISTURBANCES

Affections of bones induced by endocrine disturbances, i.e. pituitary dwarfism or gigantism, acromegaly hypothyroid dwarfism (cretinism), and hyperparathyroidism (diffuse osteitis fibrosa cystica) seldom require orthopedic treatment of a surgical nature.

PAGET'S DISEASE

Paget's disease, or osteitis deformans, is characterized by an enlargement, *softening and distortion of the bones. The disease is incurable* and the treatment is only palliative.

References

Allison, N : Tuberculosis of Bone, Arch. Surg. 2 593 1921
Badgley, C. E.: Osteomyelitis of the Ilium, Arch. Surg 28 83, 1934.
Bacon, W C.: Tuberculous Osteomyelitis of the Shafts of the Large Long Bones, Proc. Staff Meet., Mayo Clin. 16 39 1941
Blount, W P Tibia Vara, J Bone & Joint Surg 19 1 1937
—: Twentieth Report of Progress in Orthopedic Surgery p. 25 (Abst. from Surg Gynec. Obst. 35 84, 1922.
Butler E. C. B. The Treatment Complications and Late Results of Acute Hematogenous Osteomyelitis. Based on Study of 500 Cases Admitted to London Hospital during Years 1919-1937 (Hunterian Lectures, Abridged) Brit. J Surg 28 261, 1940.
Carter R. A. Coccidioidal Granuloma Roentgen Diagnosis, Am. J Roentgenol. 25 715, 1931
Cohn, Isidore: Acute Osteomyelitis. Nineteenth Report of Progress in Orthopedic Surgery p. 26 (Abst. from New Orleans M. & S. J 74 505 1922)
Conner C. L. Monilia From Osteomyelitis, J Infect. Dis. 43 108 1928.
Crossan, E. T Hematogenous Osteomyelitis. Collective Review of the Literature From 1932 to 1937 Internat. Abstr Surg 66 1 6, 1938.
Cutting, R. A.: Acute Haematogenous Osteomyelitis of Adolescence, Internat. Abstr Surg. 51 5, 1930
Dickson, F D: Clinical Diagnosis, Prognosis and Treatment of Acute Hematogenous Osteomyelitis, J A. M. A. 127 212 1945.
Finkelstein, Harry: The Correction of Rachitic Deformities by Preliminary Decalcification, J Bone & Joint Surg. 17 780 1935.
Fisher K. A. The Management of Osteomyelitis Secondary to War Wounds, Surg Gynec. Obst. 83 507 1940.
Gaenslen, F J: Split Heel Approach in Osteomyelitis of the Os Calcis, J Bone & Joint Surg 13 759 1931
Geschicter C. F., and Copeland, M. M.: Tumors of Bone New York, 1936, The American Journal of Cancer
Gurd, F B: The Treatment of Compound Fractures. A Specific Technique for the Prevention and Control of Osteomyelitis, J Bone & Joint Surg 15 327 1933.
Hawk, C. L.: The Treatment of Osteomyelitis, J Bone & Joint Surg 15 401, 1933.
Henderson, M. S., and Simon, H. E.: Brodie's Abscess, Arch. Surg 9 504 1924.
Hodges, F C. Tuberculosis of the Long Bones. A Report of Six Cases, J Bone & Joint Surg. 21 148 1939
Hsieh, C. K., Miltner L. J., and Chang, C. P Tuberculosis of the Shaft of the Large Long Bones of the Extremities, J Bone & Joint Surg. 16: 545 1934.
Jacobson, H. P: Coccidioidal Granuloma. A Clinical and Experimental Review With Case Reports, Arch. Dermat. & Syph. 21: 790 1930.
Kelly R. P: Skin-Grafting in the Treatment of Osteomyelitic War Wounds, J Bone & Joint Surg 28 681 1946
Key J A. The Early Operative Treatment of Acute Hematogenous Osteomyelitis, Surgery 9 6 1941.
Key J A.: Chemotherapeutic and Surgical Treatment of Acute Osteomyelitis, J Missouri M. A. 43 23 1940.
Knight, M. P., and Wood, G O Surgical Obliteration of Bone Cavities Following Traumatic Osteomyelitis, J Bone & Joint Surg 27 547 1945
Kulowski, J Pyogenic Osteomyelitis of the Spine. An Analysis and Discussion of 102 Cases, J Bone & Joint Surg 18 343 1936.
Magnusson, R. Tuberculosis of the Diaphyses of the Long Bones, Acta orthop. Scandinav 6 93 193.
McMaster Paul E., and Gilfillan, Charles Coccidioidal Osteomyelitis, J A. M. A. 112. 1233, 1939

Milch H : Juxta Articular Partial Tibial Osteotomy, Surg Gynec. Obst. 59 87, 1934
Mitchell, Jos. I : Acute Osteomyeliti , Southern M J 29 588 1936
Orr H. W : The Treatment of Acute Osteomyelitis by Drainage and Rest, J Bone & Joint Surg 9 733 10
—: The Treatment of Osteomyelitis and Other Infected Wounds by Drainage and Rest, Surg Gynec. Obst. 45 446, 19 7
— A New Method of Treatment for Chronic Infections Involving Bone J A. M A 80 1301 1923 (Abst *from* Nebraska State M J 8 50 1923.)
Phemister D B.: Silent Foci of Localized Osteomyeliti J A M A 82: 1311, 1924
Prigge E. K : The Treatment of Chronic Osteomyelitis With the Use of Muscle Transplant or Iliac Graft, J Bone & Joint Surg 28 5 6 1946.
Robertson I M., and Barron J N : A Method of Treatment of Chronic Infective Osteitis, J Bone & Joint Surg 28 19, 1946
Rogers W A An Operation for Benign Cyst of the Upper Humeral Metaphysis Arch Surg 46 750, 1943.
Rountree C. R Diaphysectomy for Chronic Osteomyelitis of the Fibula, Clinics 2 1010 1943.
Speed J S. An Analysis of 160 Cases of Osteomyelitis With End Results, Southern M J 15 721 1922.
Speed, J S., and Boyd, H B. Bone Syphilis, Southern M J 29 371 1936.
Speed, Kellogg Growth Problems Following Osteomyelitis of Adolescent Long Bones Surg Gynec. Obst. 34 469 1922.
Starr C. L.: Acute Hematogenous Osteomyeliti Arch Surg 4 56 1922.
Swift, W E., and Hallock, H. Treatment of Localized Fibrocystic Cavities in Bone by Curettage and Packing With Bone Chips, J Bone & Joint Surg 20 411 1938
Wilson J C. The Delayed Operative Treatment of Acute Hematogenous O teomyeliti Surgery 9 666 1941
Wilson, J C., and McKeever F M Hematogenous Acute Osteomyelitis in Children J Bone & Joint Surg 18 328 1936
Wishner J G : Chronic Sclerosing Osteomyelitis (Garré) J Bone & Joint Surg 15 723 1933.

CHAPTER XIX

TUMORS OF BONES, JOINTS, AND SOFT TISSUES

Tumors of the bone may be primary or metastatic. Primary bone tumors are either osteogenic or nonosteogenic. The osteogenic types are derived from cells or tissues which are formed in the evolutionary process of bone development, whereas nonosteogenic tumors arise within the bone from cells which normally reside in bone but are otherwise unrelated to bone or bone-forming elements. Metastatic tumors arise from malignant growths in distant organs or parts.

The more common bone tumors may be classified as follows

Primary

Osteogenic Tumors

Benign	—Osteoma (exostosis)
	Osteochondroma
	Chondroma
	Osteoid osteoma
	Giant cell (osteoclastoma)
	Xanthoma
Malignant (sarcoma)	—Chondromyxosarcoma (primary and secondary)
	Osteoblastic
	Chondroblastic
	Osteolytic

Nonosteogenic Tumors

Benign	—Angioma
Malignant	—Endothelial myeloma (Ewing's Tumor)
	Myeloma
	Periosteal fibrosarcoma

Metastatic

Carcinoma
Lymphosarcoma
Hypernephroma

With few exceptions, benign tumors of bone should be excised as all are potentially malignant Other affections of bone such as Paget s disease, also frequently undergo malignant changes So far as treatment is concerned, bone tumors need be distinguished merely as to whether they are benign or malignant Whether the cells in a benign tumor undergo malignant change or malignancy originates within the tumor from embryonic rests, is of no practical importance

BENIGN TUMORS OF BONE

OSTEOMA (EXOSTOSIS)

An osteoma is a benign outgrowth of normal cancellous or cortical bone. True osteomata originate from membranous bones, such as those of the face and skull Histologically they consist of discrete, eburnated, compact bone or spongy bone or present an ossifying fibromatous quality The distinction of the latter type from a sarcoma may be particularly confusing to the pathologist. Simple excision of the lesion will effect a cure

Calcaneal spurs and osteophytes of the spinal column though bony excrescences, can hardly be classified as neoplastic lesions.

OSTEOCHONDROMA

A large proportion of osteochondromata arise adjacent to the knee joint, either from the lower end of the femur or upper end of the tibia. The remainder are located adjacent to the ends of other long bones. These tumors do not originate in the epiphyses or the bone proper, according to Geschickter and



Fig. 823.—*A*, Osteochondroma of distal end of proximal phalanx of finger. Extreme angulation from growth of tumor. *B*, Treated by excision of distal half of proximal phalanx and removal of sufficient bone from middle phalanx to correct angulation.



Fig. 824.—Osteochondroma of lower end of tibia, associated with multiple osteochondromata. Note lateral bowing of fibula from pressure of tumor. Treated by excision of tumor and osteotomy of fibula, with alignment of fragments.

Copeland, but are derived from precartilaginous tissue adjacent to epiphyses and from a protuberance of bone which grows through a break in the periosteum intended for an attachment of a tendon The tendon does not become attached to this raised knucklelike growth of bone instead an overgrowth of the tissues ensues. This consists of bone, both compact and cancellous, adult hyaline cartilage undergoing calcification in its deeper portion and connective tissue, from the deepest to the most superficial layers, in the order named. This explains the presence of osteochondromata at the points of tendinous attachments to bone. Etiologically, these tumors may have a congenital or familial background or may be of traumatic origin

The base of the osteochondroma merges with the cortex of the bone, having either a broad base or narrow pedicle. The most important portion of the tumor from a clinical and surgical standpoint is the cartilaginous cap which usually is small and definitely outlined. If the cap is hazily outlined as a large, cauliflower shaped growth, the tumor may be malignant In a series of cases reported by Geschickter and Copeland 7 per cent of benign osteochondromata developed subsequent malignant changes. Whatever the type, the tumor must be removed below the base with its cartilaginous portion intact, in order to prevent recurrence. Even though one might disregard excision as a prophylaxis against malignant degeneration, the procedure frequently is necessary because of interference with the function of the adjacent joint. Since these tumors, particularly if about the knee, are subject to constant trauma a more or less painful bursa often forms over the most prominent portion

A description of the technic for excision of osteochondromata from the lower and upper ends of the femur and upper end of the humerus will suffice. The principles of these operations are applicable to tumors in other locations, the exposure in each case following the anatomic lines of the area involved.

Excision of Osteochondroma From Lower Medial Portion of Femur

Technic.—A longitudinal incision is made over the prominence of the tumor if palpable or over the location as demonstrated by the roentgenogram. The vastus internus muscle is exposed and divided with a blunt instrument or sharp knife in the direction of its fibers. A bursa, if found over the prominence of the tumor may usually be resected intact with the tumor otherwise, the incision may be carried through the bursa to the tumor With a periosteal elevator the tumor is completely exposed and the periosteum incised about its base. The tumor is next grasped just below the cartilaginous surface by means of bone-holding forceps and resected, together with a small portion of the normal shaft. The tumor may then be delivered with the bursa, cartilaginous cap and base intact. If the bursa is not removed entirely with the tumor the remaining portion is dissected out Should a tendon insertion be intimately associated with the tumor the fibers should be resected with the tumor and the tendon reinserted at another location. Muscle or fascia is sutured over the raw area of the bone

Recurrences should be rare if resection is thorough

Excision of Osteochondroma From Upper End of Femur

When the tumor forms a mass having a broad, indefinitely outlined attachment over a large area, excision must be made along an arbitrary line which will include all abnormal bone This type of osteochondroma may be found in the region of the trochanters of the femur If around the lesser trochanter

excision is particularly difficult since adequate exposure is not readily obtained. The mass may be most prominent anteriorly or posteriorly, as determined by a lateral roentgenogram.

Technic.—If the tumor protrudes posteriorly, a curved incision beginning just below the mid portion of the posterior crest of the ilium is extended downward and outward in line with the fibers of the gluteus maximus muscle



Fig. 325.—Multiple osteochondromata (Ollier's disease). Prominent tumors which are subjected to trauma should be excised. Seven per cent of osteochondromata eventually become malignant.

thence curved distally just below the trochanter, following the shaft of the femur a distance of two inches. By blunt dissection, the fibers of the gluteus maximus muscle are divided over the prominence of the tumor down to its insertion into the iliotibial band and the gluteal tuberosity of the femur. The

gluteus maximus is then detached from the bone and one half is retracted proximally the other half distally The quadratus femoris and adductor magnus muscles are next separated, bringing the tumor into view If the posterior portion of the neck of the femur is involved in the mass, the quadratus muscle is detached from its insertion and retracted toward the midline. The posterior femoral cutaneous and sciatic nerves are in the immediate field of operation emerging beneath the lower border of the pyriformis muscle, and must be carefully isolated and retracted (p 149) With a periosteal elevator the mass is completely exposed. The periosteum around the tumor is incised and the base of the tumor including the lesser trochanter and the portion of the shaft or neck of the femur involved in the growth is resected with a chisel. If the cap is an extensive cauliflower like mass, many of the small cartilaginous remnants will adhere to the soft tissues. These must be thoroughly excised otherwise there may be a recurrence. *Every possible fragment of the tumor is likewise removed from the neck,* trochanter and shaft. All muscles are reattached at their normal insertions with No 1 chromic catgut, with the exception of the iliopsoas muscle no attempt is made to suture this structure to the lesser trochanter



Fig. 826.—*A* Osteochondroma of neck and trochanter of femur *B* After excision.

If the tumor protrudes anteriorly an incision beginning at the anterior superior spine is continued onto the anterior surface of the thigh in line with the lateral border of the sartorius muscle. Blunt dissection is carried between the sartorius and tensor fasciae femoris, and the rectus femoris and vastus lateralis muscles. The hip is then placed in external rotation which exposes the tumor The technic thereafter is similar to that just described.

Osteochondroma of Pelvis

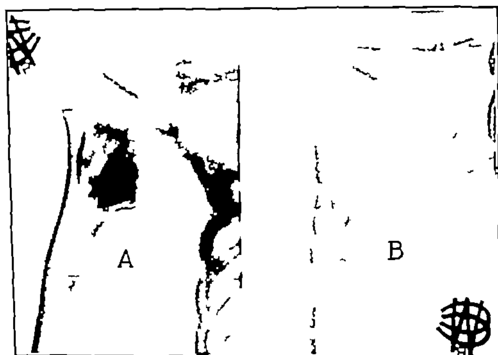
Ghormley in a study of forty cases of osteochondroma of the pelvic bones, has pointed out the seriousness of so-called benign lesions about the pelvis. Excision of these lesions, particularly if not pedunculated and if situated in the more remote and inaccessible parts of the pelvis, may be extremely difficult Ghormley and associates resorted to interinnominoabdominal amputations in order to eradicate some of the tumors which had reached large proportions.

Excision of Osteochondroma From Upper End of Humerus

Osteochondromata situated on the medial anterior or lateral aspect of the per end of the humerus usually are easily exposed and removed through Henry incision (p 154) Since tumors on the posterior aspect are excised th a little more difficulty the technic for these will be given in detail

Usually, osteochondromata in this area are observed just distal to the per humeral epiphysis and have a relatively narrow base In children the ny mass may be palpated guiding one in the location of the incision

Technic.—Beginning just distal to the acromion process of the scapula the in is incised longitudinally two or three inches over the prominence of the mor posteriorly In proceeding through the deltoid muscle by blunt dis- ction the axillary nerve and posterior humeral circumflex vessels should be entified and carefully isolated These structures pass through the quadri teral space i e between the subscapularis and teres minor muscles above the



ig. 37—A Osteochondroma of upper portion of humerus. B. Treated by excision. No recurrence.

eres major below the long head of the triceps brachii and the surgical neck f the humerus. The anterior or upper branch of the axillary nerve winds round the surgical neck of the humerus beneath the deltoid to its anterior order Injury to this nerve will cause practically complete paralysis of the eltoid muscle for this reason, the assistant who holds the retractors should e cautioned against undue trauma and excessive traction.

If the osteochondroma is below the surgical neck of the humerus, a portion f the lateral head of the triceps brachii may be incised longitudinally and re- racted sufficiently to expose the base of the tumor Excision is then effected by method similar to that described above for tumors of the lower end of the emur

CHONDROMA

Chondroma may be centrally located as an enchondroma of the small bones f the hands or feet or rarely of the long bones, or as a large cauliflower like

mass of the sternum or spine. An enchondroma of the small bone originates from prechondrial connective tissue which normally forms the *joints*. Microscopically these neoplasms of the small bones are, usually not particularly cellular and thorough curettage effects a cure. The cavities are obliterated with bone grafts, as described for bone cysts (p. 1154). Larger and less accessible chondromata



Fig. 623.—Enchondroma involving entire shaft of humerus. Treated by amputation through shoulder joint.

about the spinal column or trochanteric region of the femur reveal more chondrogenetic activity and are far less amenable to surgical treatment. If all of the *neoplasm is* not removed, growth will continue to a fatal termination. Although chondromata are highly resistant, the larger tumors should be treated by roentgen therapy. One of our patients who had a chondroma of the trochanter

and neck was treated surgically, though the tumor was not completely removed This was followed by roentgen therapy, and the patient is living eleven years later without further growth of the chondroma

Rarely, chondromata are observed as expansile growths of the ends of long bones (Fig 828) For these lesions, treatment is carried out as for a giant cell tumor

OSTEOID OSTEOMA

Osteoid osteoma is a slowly growing benign osteogenic tumor As defined by Jaffe in 1935 the original phase of its evolution is characterized by the proliferation of the local bone forming mesenchyme particularly the osteoblasts In this stage, the tumor may consist largely of a vascular mesenchymal substratum closely packed with osteoblasts though showing also a scattering of osteoclasts For more complete details of the pathology and other aspects of this tumor the reader is referred to the authoritative articles by Jaffe and his co-workers.

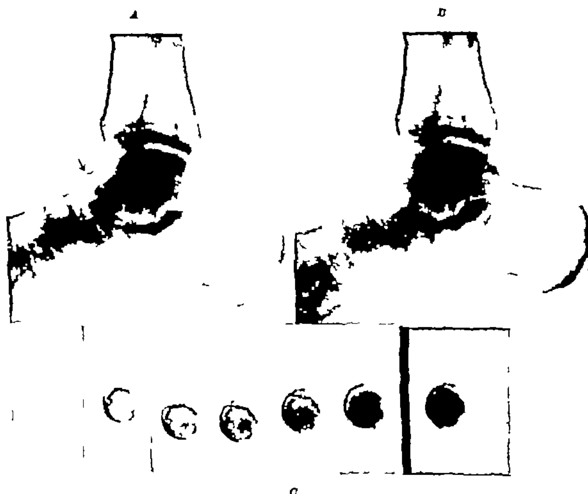


Fig 829.—Osteoid-osteoma of astragalus. *A*, Circular lesion 14 x 14 mm. in superior portion of neck of astragalus. Approximately one-half of lesion protrudes above cortex. Center is radiolucent, while margin is sclerotic, and this in turn is surrounded by another radiolucent area. *B* Roentgenogram after removal of nidus a small, rarefied area is left in neck of astragalus. *C* Surgical specimen with small rim of perifocal bone Roentgenograms made with varying degrees of intensity of exposure. (*From* Hamilton, J F Surg., Gynec. & Obst. 81: 465, 1945.)

The tumor develops most often in patients in the second and third decades of life and is characterized by exquisite finger point pain and tenderness over a small area of a bone Occasionally congestion and edema of the adjacent periosteum give rise to swelling of the overlying soft tissue though local fever and redness of the skin are rare

The first roentgenograms may be negative, or the lesion may be so minute that it cannot be seen until three or more months after the onset of pain. A typical osteoid osteoma is revealed in the roentgenograms as an oval or round area from a few millimeters to one or two centimeters in its greatest diameter the center of this lesion manifests small areas of rarefaction. The surrounding parent bone is as a rule sclerosed for a variable depth.

Osteoid osteoma may arise in the cortex just beneath the periosteum in tracortically or in cancellous bone. A tumor in the cortex produces a much greater defensive response in the form of pronounced thickening and condensation of the proliferative periosteal and endosteal bone (Fig 807) The response to tumors of the cancellous bone is much less definite.

Prior to surgery for an osteoid osteoma roentgenograms in different views should be made until the nidus can be exactly located. If the lesion is in the cortex, the nidus may be obscured by the dense periosteal bone laid down by the periosteum The resection of unnecessary amounts of bone may be avoided by careful preoperative planning Surgery consists of eradication of the nidus. Since this area is relatively small usually a substantial section of bone in the area of the nidus is resected and then sectioned, that one may be certain the nidus has been completely removed After excision the defect may be sufficiently large to warrant eradication by bone grafts.

The location of a nidus may be facilitated by the insertion of a drill point in the region of the nidus Two-view roentgenograms are then made and dissection is carried out, the drill being used as a landmark. In spongy bone the nidus may usually be eradicated with a curette.

The prognosis of this tumor following surgical excision is excellent. If incompletely removed the tumor will continue to grow and produce pain.

GIANT CELL TUMOR (OSTEOCLASTOMA)—XANTHOMA

Giant cell tumors or osteoclastomata are generally located in the lower end of the femur upper end of the tibia, and distal end of the radius. Operative interference is always justified first, as a curative measure and, second, for diagnostic purposes.

The differentiation of benign and malignant giant cell tumors from osteolytic osteogenic sarcoma and metastatic carcinoma is of primary importance. In the first place it is extremely doubtful that there is such a tumor as a malignant giant cell tumor A metastatic lesion with the same type of stroma *cell as that of a benign giant cell tumor has not been definitely proved.* The reported so-called malignant giant cell tumors with metastasis and death, were probably osteolytic osteogenic sarcomata

A typical giant cell tumor arises in the epiphysis of a long bone generally the lower end of the femur the upper end of the tibia and the lower end of the radius, and rarely in the shaft of a long bone The tumor tends to expand the epiphyseal end of the bone breaking through the cortex and occasionally growing into the adjacent joint. It is frequently marked by coarse or fine bony trabeculae giving it a multilocular cystic appearance. Growth is slow and as a rule, the symptom of pain sends the patient for examination in the third decade of life

Osteolytic osteogenic sarcoma develops most often in the metaphysis of a long bone This is an explosive type of lesion. Growth proceeds so rapidly and lytic properties are so pronounced that the cortex does not expand Because of the histologic picture of malignant fibroblasts numerous abortive

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malignant osteoblasts large dusty nuclei many mitotic figures and epulis like giant cells or multinucleated tumor giant cells the distinction from benign giant cell tumor is made with relative ease

A metastatic carcinomatous lesion is observed so seldom in the sites common to giant cell tumor and osteolytic osteogenic sarcoma as to be hardly worth considering here Microscopic study of a biopsy specimen is the final answer to all of these diagnostic problems

Xanthoma is a type of giant cell tumor which, grossly, is yellow in color and histologically presents occasional foam cells. This tumor has no relationship to disturbances of cholesterol metabolism Treatment is carried out as for giant cell tumor

The measures for treatment of giant cell tumor are as follows (1) Roentgen ray therapy, (2) Curettage and bone grafts (3) Resection (4) Resection and bone graft (5) Amputation

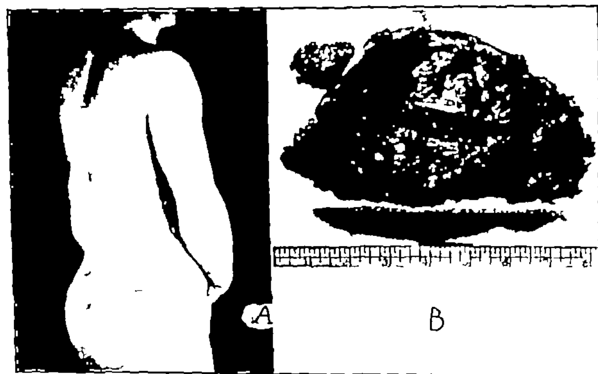


Fig. 110.—*A* Chondroma originating on spinous process and lamina of second lumbar vertebra. *B* Specimen after excision. Patient received extensive roentgen therapy After two years, there is evidence of beginning recurrence of the tumor

Roentgen Ray Therapy

Preoperative irradiation by radium or the roentgen ray has not proved sufficiently curative to warrant a prolonged delay of operative interference Further in doubtful cases biopsy and a microscopic diagnosis should precede irradiation therapy Postoperatively this form of therapy is of questionable value in preventing recurrences of lesions, and as a treatment of recurrences according to Geschickter and Copeland is practically worthless.

Curettage and Bone Graft

Curettage and obliteration of the cavity with bone grafts is the treatment of choice in all cases other than those wherein resection is indicated. Even after recurrence a second curettage is advisable for tumors in certain locations as

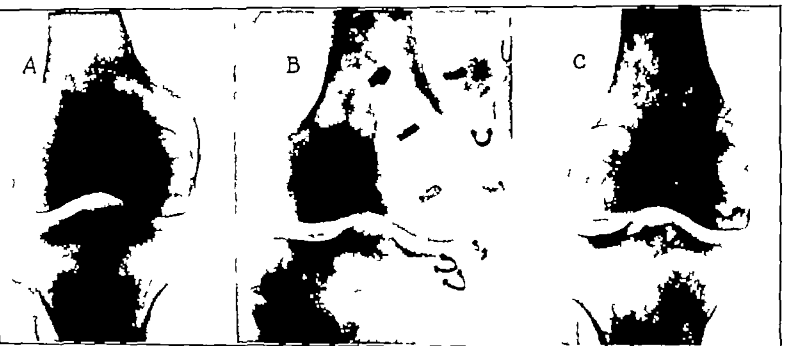


Fig. 831.—*A* Giant cell tumor of internal condyle of femur. *B* After thorough curettage, cavity was so large that amputation was contemplated, but deferred; instead, cavity was cauterized and filled with bone chips. *C* Eight months postoperatively cavity practically filled with callus and new bone.

the lower end of the femur, because of the extreme difficulty of securing a serviceable member after resection or the less desirable alternative amputation

The technic is similar to that employed for removal of bone cysts (p 1154) The procedure must be thorough Bloodgood, Geschickter and Copeland and others have recommended cauterization of the cavity with phenol or a solution of zinc chloride or the use of a thermocautery The contents of the tumor should be preserved for microscopic section

Ordinarily we do not cauterize the cavity Cauterization devitalizes the bone interferes with healing and is followed by sufficient necrosis to form an excellent pabulum for infection This is a real disadvantage and we feel out weighs any advantage so far as recurrence of the tumor is concerned

After evacuation the cavity is filled with bone chips or cancellous bone from an adjacent area of normal bone or from the upper end of the tibia For large cavities, an ample quantity of bone may be obtained from the ilium Homogenous grafts from the bone bank offer many advantages Frequently the bone has been so widely destroyed that thorough fixation and immobilization must be maintained until healing is complete in order to prevent a pathologic fracture In some cases, the dual onlay bone graft as advocated by Rogers for certain bone cysts (p 1158), might be applicable

Resection—Resection and Bone Graft

Resection of a tumor is indicated in the following conditions

1. When functional disability will be of a minor degree, as in the upper portion of the fibula metatarsal bones, distal end of the ulna, and proximal end of the radius. Even in these locations, curettage is indicated if the lesion is small and well localized.

2. If destruction of bone is so extensive that curettage is not commensurate with a cure or with subsequent function of the part, particularly if a graft can be substituted for the resected bone This is most often employed in the distal end of the radius.

Bone grafts occasionally may be applied following resection of bone from the lower extremities. Substitution of a large area of resected bone by grafts, however is much less successful in the lower extremity than in the upper since in the former considerable stress is placed upon the graft on weight bearing (See Defects of the Shafts of the Long Bones) Further when the tumor is adjacent to the knee joint, restoration of function by the use of a graft is not possible as the joint is destroyed. Obliteration of the defect by apposition of the ends of the tibia and femur would produce excessive shortening and thus a rather functionless extremity

In the subsequent section, the technics of resection of bones which are rarely the sites of giant-cell tumors are described. Most of the sites amenable to resection are described herein, to prevent repetition elsewhere (Fig 833)

Resection of Os Calcis With Tendon Transplantation or Replacement by a Bone Graft

Tumors of the os calcis are exceedingly rare the usefulness of the following plastic procedures after resection of the os calcis, therefore, is definitely limited. Moreover the advisability of resection of the os calcis in preference to amputation through the middle and lower thirds of the leg is questionable, since the disability incident to amputation and the use of an artificial limb may be

less than that following resection Miltner and Wan describe a technic which *they employed in one case of giant cell tumor of the os calcis accompanied by* destruction too extensive for curettage.



Fig. 832.—A Giant cell tumor involving practically all of condyles of tibia. Treated by curettage. Cavity filled with bone chips. B Result ten years postoperatively

Technic (Miltner and Wan).—The entire os calcis is removed through a wide U-shaped incision (p 171) The tendo achillis is then lengthened and its lower end fastened to the posterior inferior part of the astragalus by means of sutures passed through drill holes in the bone.

Fig 833

Resectable Portions of the Skeleton

Bone	Disability*	Reconstruction
Phalanges of all toes (amputation or resection)	None to mild	Unnecessary
Metatarsals—first should be spared if possible (amputation or resection)	Mild to moderate (2, 3, 4, 5) (1)	(1) Shifting of bases of other metatarsals with amputation of distal end of ray (Fig 1069) (2) Bone graft (p. [illegible]8)
Any tarsal bone except os calcis† (amputation or resection)	Mild to moderate	(1) Resection of compensatory wedges and triple arthrodesis (p. 1320) (2) For astragalus: Calcaneotibial fusion (p 387)
Proximal 4/5 of fibula	None to mild	Unnecessary (p 129)
Distal 1/3 of fibula	Mild to moderate	Bone graft: Replace with proximal ½ of fibula (p. 1182)
Distal 3/4 of internal malleolus	Mild	Unnecessary if angle of mortise preserved (p. 636)
Patella	Mild	Unnecessary (p. 40[illegible])
Ischium Coccyx Spinous processes, etc Ribs	None to mild	Unnecessary (p 1186 p. 280 p. 87[illegible])
Major portion of ilium except acetabular portion and S.I joint must preserve continuity	None to mild	Unnecessary (p. 1145)
Medial or lateral 1 to 1½" of clavicle Entire clavicle	Mild Moderate	Unnecessary (p 355)
Acromion	None to mild	Unnecessary (p. 844)
Entire scapula or segment of wing	Severe to moderate	Unnecessary (p. 1188 and p 1189)
Head and tuberosities of humerus	Moderate	Tendoplastic (p. 472)
Upper 2/3 of humerus	Severe	Fibular transplant (p. 1191)
Olecranon	Mild	Unnecessary (p. 49[illegible])
Epicondyle	None to mild	Transference ulnar nerve may be indicated (p. [illegible]73)
Capitellum in adult	Mild to moderate	Supracondylar osteotomy for cubitus valgus (p. 570) Arthroplasty (p. 1118) Arthodesis (p. 958)
Head and neck of radius	None to mild	Unnecessary (p. 494)
Distal 2" of ulna	None to mild	Unnecessary (p. 597)
Distal 1/3 of radius	Mild to moderate	Replacement by proximal 1/3 of fibula (p. 1193)
Any or all of carpal bones	Mild to moderate	Unnecessary or arthrodesis (p. 987)
Metacarpals—spare first if possible (amputation or resection)	Mild to severe (2 3 4 5) (thumb)	(1) Bone graft (p. 1194) (2) Shifting bases of remaining metatarsals with amputation of affected ray
Phalanges of fingers (amputation)	Mild	Unnecessary
Six inches or less of shaft of any long bone; femur and tibia least desirable	Moderate to severe	(1) Dual grafts (p. 703) (2) Hemicylindrical grafts (p 703)

*The disability estimate is that which is residual after available reconstruction procedures.

†Resection of os calcis and replacement by a graft is possible (p. 1179) but amputation through the middle and lower third of the leg is most practical.

FIG 834.

RESECTION OF JOINTS WITH ADJACENT BONE

JOINT	DISABILITY	RECONSTRUCTION
Knee with metaphyses of upper tibia or lower femur	Severe	Dual grafts to bridge defect (p. 703) Hemicylindrical grafts (p. 703)
Hip with head, neck and/or trochanter and portions of ilium	Moderate to severe	Arthrodesis of stump to ischium (p. 962)
Shoulder with acromion, head and tuberosities of humerus	Moderate	Teno plastic reconstruction (p 473)
Elbow joint	Moderate	Accept unstable joint (p. 916) or arthrodesis (p. 953)
Carpus and minimal resection of distal end of radius	Mild to moderate	Arthrodesis (p. 987) and resection of distal ulna (p. 597)

After Treatment.—A boot cast is applied with the foot in 135 degrees plantar flexion. Two months later the cast is removed and physical therapy begun, the foot remaining immobilized in a removable splint which holds the foot and ankle in 135 degrees' plantar flexion. Three months postoperatively a brace with a light steel spring at the ankle, is fitted. The spring aids in plantar flexion and maintains the foot and ankle in approximately 105 degrees plantar flexion, thus preventing a severe calcaneal limp A three fourths-inch elevation is inserted in the shoe.

Schmidt reported the use of a portion of the crest of the ilium, including the anterior spine to replace the os calcis after resection. The anterior superior spine served as a tuberosity the tendo achillis being fastened to the graft. Although Schmidt obtained an excellent result this procedure would rarely be justified.

Resection of Lower Third of Fibula, With Substitution by a Fibular Graft

Carrell has devised an ingenious procedure for restoration of the ankle mortise following resection of the lower third of the fibula He reported two cases wherein the fibula was resected, one for hemangioma the other for Ewing's sarcoma in both of which the result was satisfactory We have utilized a variation of this procedure for a chondroma of the distal end of the fibula the cosmetic and functional result was excellent.

Technic (Carrell).—Through a straight lateral incision the lower third of the fibula and entire external malleolus are resected with the tumor intact. Through a separate incision, the proximal portion of the fibula is released by stripping of the soft tissues from the periosteum The attachment of the biceps femoris muscle is sutured to the fascia lata and the capsule of the fibula. The proximal segment of the bone is then reversed drawn through the lower incision, and transplanted to the ankle joint. The apposing surfaces of the shafts of the fibula and tibia are roughened and the head of the fibula is placed against the side of the astragalus to form a new external malleolus. A screw holds the graft firmly in position against the tibia If the entire shaft of the fibula is resected the proximal third of the opposite fibula may be used as a transplant to reconstruct the external malleolus.

In children, the upper fibular epiphysis is preserved without injury as a part of the transplant. The graft is imbedded into the tibia just proximal to the epiphyseal plate and directed outward from the tibial epiphysis as it crosses the ankle joint

If preferred, the lower end of the fibula may be resected and the astragalus fused to the tibia.

Resection of Lower End of Femur With Substitution by a Tibial Graft

This procedure is so extensive and so often unsuccessful that its use should be restricted to young adults with excessive destruction of bone In elderly or middle-aged individuals with excessive destruction amputation is always preferable

Technic.—The knee joint and lower portion of the femur are exposed through a long anteromedial incision The deep structures are incised well proximally the vastus medialis muscle being separated from the quadriceps tendon. The quadriceps tendon the patella, and patellar tendon are retracted laterally and the knee is flexed The lateral ligaments are severed from their attachments to the condyles of the femur and the cruciate ligaments incised. Both semilunar cartilages are resected After a subperiosteal dissection of the attachment of the posterior capsule of the femur the joint is dislocated causing the femoral condyles to protrude through the wound The amount of bone removed depends upon the extent of the tumor usually, both femoral condyles and a portion of the metaphysis must be excised The bone is divided from before backward one inch proximal to the tumor The proximal segment is grasped with bone holding forceps and dissected out posteriorly from above downward The articular surface of the tibia is then denuded The space between the distal end of the femur and the tibia should not exceed three inches.

The defect is bridged by a dual onlay graft. To provide stable fixation the grafts must be sufficiently long to extend at least two inches proximal and distal to the defect. With allowance for one inch shortening by a decrease in the size of the defect the graft should be one and one half inches by six inches. Such large grafts should be taken from the bone bank. The bone-grafting procedure is carried out in essentially the same manner as in long bones (p 707) The trough between the dual grafts should be filled with generous amounts of cancellous bone from the ilium

As an alternative to this technic, a massive graft, consisting of the anterior half of the tibia on the affected side, may be utilized, as follows After resection of the lower end of the femur the incision is extended distally along the tibial crest to the junction of the middle and upper thirds of the leg and the patellar tendon is detached. The upper third of the tibia including the condyles, is split in half from side to side and the anterior half is removed. In applying this graft, the ends are reversed, so that the distal narrow portion approximates the anterior surface of the femur, the broad extremity or condylar portion being in contact with the posterior half of the condyles. The massive hemicylindrical type grafts described by Flannigan (p 710), for bridging defects in the tibia or femur might also be applicable

Following either of the above methods, generous amounts of bone shavings and cancellous bone are packed around the grafts and in the defect between the tibia and femur

After Treatment.—The extremity is encased in a plaster cast from the crest of the ilium to the toes on the affected side and to the knee on the opposite side Support by the cast is continued for at least six months to allow complete union of the graft and bones. A leather lacer brace with a pelvic band attached (p 38) is then fitted from the groin to the ankle, the shoe on

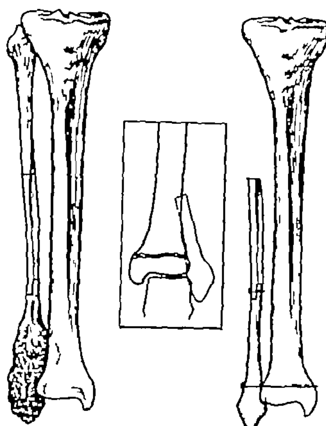


Fig. 835.—Variation of Carrell technic for replacement of distal end of fibula by proximal e Insert shows method of transplantation if distal tibial epiphysis is active.



Fig. 836.—Enchondroma of distal end of fibula recurred following curettement elsewhere patient aged 18 years. Two possibl methods of treatment resection of tumor and replacement by whole fibular graft, o resection with arthrodesis of ankle joint.

the foot is elevated to insure weight bearing on the normal extremity, and the patient is allowed to walk with the aid of crutches After the elapse of six months to one year weight bearing is gradually resumed By active use of the extremity bone production will be stimulated and the dimensions of the graft increased

Phemister describes a similar procedure carried out for a so-called malignant variant of a giant cell tumor of the lower end of the femur He resected the knee joint together with the lower portion of the femur and the proximal



Fig 637 —Same as Fig 636, nine months after transplantation of proximal end of fibula to replace distal end. Patient served four years in army in limited service capacity now works as a mechanic.

one half inch of the tibia Two large tibial grafts were then inserted into the cancellous intramedullary portion of the tibial condyle and fixed to the shaft of the femur and to the tibia by two threaded pins at each end He also reports a case of chondrosarcoma wherein he resected a six inch section of the shaft of the femur Dual grafts were used to bridge the defect one being inserted as an intramedullary graft the other as an onlay graft. Both of these patients obtained a good result, the defect having filled in adequately and were living four and four and one half years respectively after the operation

Resection of the Ischium

Partial or complete resection of the ischium may be indicated in the presence of tumors, tuberculosis, or osteomyelitis. Proper exposure of this area either for the purpose of biopsy drainage or resection, is afforded by the following technic.

Technic (Milch) —With the patient in the lithotomy position and with the buttocks elevated, the tuberosity of the ischium the inferior border of the body of the pubis and the intervening subcutaneous rami are palpated. An incision is then made along this subcutaneous, bony ridge and is continued

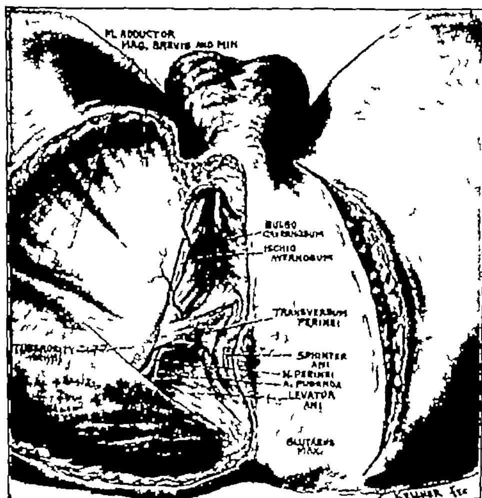


Fig. 838 —Exposure of ischium for biopsy or resection. Line of incision, and superficial structures exposed. (From Milch, Henry J Bone and Joint Surg. 17 166, 1935.)

for about three or four inches posteriorly in the skin covering the gluteus maximus. The lower edge of the gluteus is defined and is elevated with the finger so that the fibers which overhang the tuber ischii may be cut across, exposing the tuberosity of the ischium, with the attachment of the hamstring muscles and the sacrotuberous ligament along its inner border At this margin, between the two last mentioned structures, the periosteum over the tuber ischii is incised. By a subperiosteal dissection the hamstring muscles are detached and displaced laterally The periosteal incision is then carried forward along the rami of the ischium and pubis in the line of separation between the adductor muscles laterally and the perineal muscles medially As the

ocedure is carried forward, the adductor magnus is separated and displaced terally, until the lower external portion of the bone is exposed Proceeding eper into the wound, the adductors quadratus, brevis, and longus and finally e obturator externus are separated, exposing the lower rim of the obturator ramen, and displaced outward in one large flap, which *contains the sciatic* erve During the course of this dissection, no important structures are met ith and no serious hemorrhage need be feared

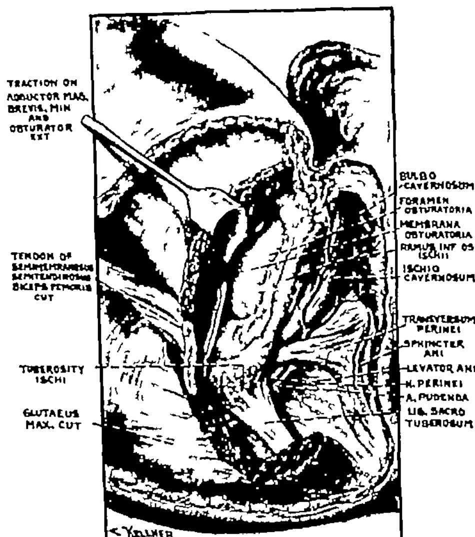


Fig. 339.—Same as Fig. 338 Anatomic plan of structures exposed in subperiosteal dissection of outer surface of ischium. (From Milch, Henry J Bone and Joint Surg. 17: 166, 1935.)

The exposure of the medial wall is rendered only slightly more hazardous by the presence of the internal pudendal vessels. However if, after separating the superficial structures, the ischiocavernosus, and transversus perinei, the dissection is kept strictly subperiosteal, the pudendal nerve and vessels will be elevated without any danger and the lower fibers of the obturator internus will be exposed in the depths of the wound These can now be raised freeing the whole of the lower margin of the obturator foramen. In the posterior part of the incision, the attachment of the sacrotuberous ligament is now sharply cut away from the tuber ischii, and the lesser sacrosciatic foramen is opened Here care must be exercised to avoid injury to the pudendal vessels, as they wind around the spine of the ischium With caution,

they may be subperiosteally freed and displaced off the spine so that resection may be carried out at or above the level of the spine. For the most part, however the inferior margin of the spine, which can be readily seen or palpated, should determine the upper level of the osteotomy of the ischial ramus. The area to be resected is now clearly exposed A Gigli saw is passed through the obturator foramen and the pubic ramus is cut through. With the saw or an osteotome the descending ramus of the ischium is cut on a line which runs from below the ischial spine beneath the lower rim of the acetabulum into the obturator foramen In clean cases, a layer by layer closure is performed In infected cases, a large cavity is left permitting adequate drainage

"For a resection of the tuberosity alone, the posterior part of the skin incision may be varied by making it in the gluteal fold at right angles to the described approach. This exposes the fibers of the gluteus maximus, which may be either retracted or cut across to gain access to the tuberosity The rest of the dissection is identical with that previously described for the posterior part of the operative field. '

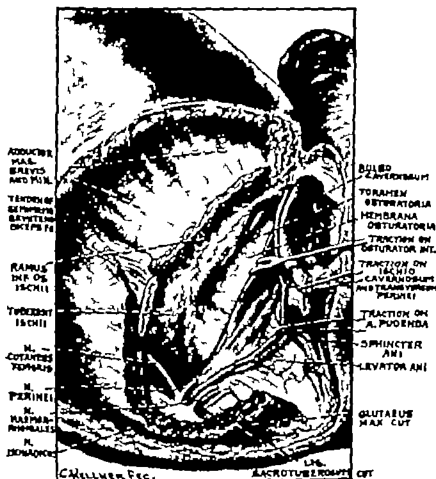


Fig. 840.—Same as Fig. 838. Exposure by subperiosteal dissection of medial aspect of tuberosity and ramus of ischium. (From Milch, Henry: J. Bone and Joint Surg. 17: 166, 1935.)

Resection of Scapula

Ryerson reports a case of resection of the scapula for metastatic carcinoma. The patient refused an interscapular thoracic amputation. Carrell

Phelps, Coley and others have reported scapulectomy for osteochondroma endothelioma and a sarcoma originating in the infraspinatus muscle. In addition to tumors this procedure might also be applicable to isolated cases of chronic osteomyelitis.

Technic (Ryerson).—The scapula is exposed by an incision passing from the acromion along the spine of the scapula to the medial border thence distally to the inferior angle. The ligaments of the acromioclavicular joint are divided. The incision along the acromion and the spine of the scapula separates the insertion of the trapezius and the origin of the posterior and middle portions of the deltoid muscle. The trapezius is retracted and by sharp dissection the muscles along the medial border and angle of the scapula (rhomboids, levator scapulae, teres major and serratus magnus muscles) are separated.

To facilitate exposure of the coracoid process and the tendons of the short muscles of the shoulder the deltoid muscle is further detached from the acromion process and the inner one inch or so of the clavicle. The coracoid process is divided, releasing the origin of the coracobrachialis and short head of the biceps and the insertion of the pectoralis minor muscle. The horseshoe shaped incision is made in an anterior posterior direction in general conforming to the medial border of the lesser and greater tubercles severing the subscapularis, long head of the biceps, supraspinatus, infraspinatus, teres minor tendons, the coracohumeral ligament and most of the capsule. After the remainder of the capsule of the shoulder joint and the other soft tissue attachments are severed, the scapula may be removed. The head of the humerus is then anchored by catgut sutures through the greater tubercle and clavicle. The trapezius and deltoid muscles are then anchored by additional sutures. Cigarette drains are inserted in the most dependent portion of the wound.

After Treatment.—The arm is immobilized by a Velpeau dressing until healing is complete. The drains are removed after thirty-six to forty-eight hours.

A procedure of this magnitude is usually performed only as a lifesaving measure, preservation of function being a secondary consideration. Obviously scapulectomy will interfere materially with the function of the shoulder joint.

Resection of Wing of Scapula

Partial resection of the scapula varying from removal of a small isolated section to excision of the entire wing of the bone may be utilized for a benign tumor, tuberculosis or chronic osteomyelitis. The acromion, the glenoid and the coracoid process being undisturbed, the humerus is maintained in relatively good position with a fairly functional and stable shoulder. A substantial bony attachment is preserved for the trapezius and deltoid muscles.

Phelps reports a case wherein he excised the infraspinatus portion of the scapula in a 7 year-old child for an exostosis of the scapula and reattached the muscles in such a way as to preserve function.

Technic (Phelps).—An incision was made along the spine of the scapula to the vertebral border and thence to the inferior angle. The trapezius muscle was divided and retracted medially and upward. Subsequently the following muscles were detached from the scapula: the rhomboids, the infraspinatus, the subscapularis, the latissimus dorsi, the serratus magnus, the teres major and the teres minor. This freed the scapula in such a way that it could be

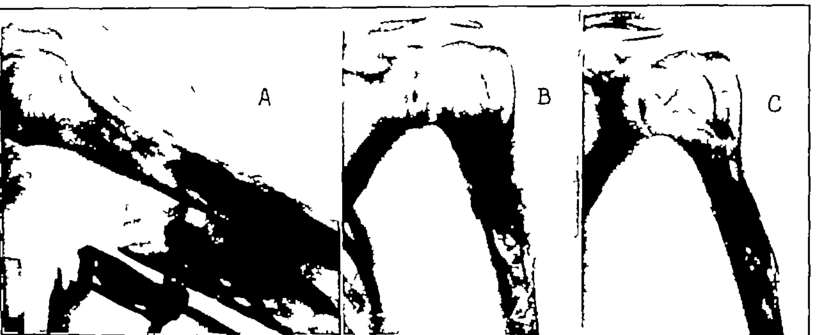


Fig 841.—*A* Pathologic fracture of upper third of humerus treated by Dr H. W Dierkesheide, in 1933 followed by solid union. No symptoms for two years. *B* On first examination, in January, 1935, definite soft tissue tumor found, with extensive destruction of upper portion of humerus. Biopsy revealed Ewing' tumor *C* Marked improvement under regime of extensive roentgen therapy and Coley's toxins.

retracted to expose the growth on the undersurface The exostosis was then removed along the wing of the scapula from its spine downward by means of bone-cutting forceps The muscles were then reattached as follows the subscapularis muscle was sutured at its lateral border to the teres major and to the serratus magnus at its vertebral border leaving the sheath of the muscle between the subscapularis and the infraspinatus intact The infraspinatus muscle was sutured to the teres minor on its axillary border the serratus magnus on its vertebral border and the combined attachments of these muscles were sutured to the rhomboids. The trapezius muscle was replaced over the rhomboids.

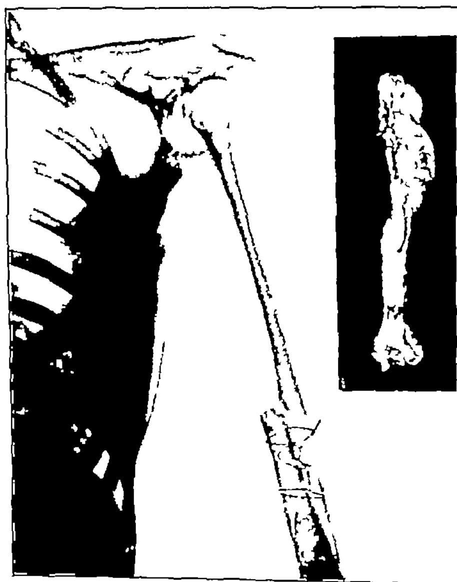


Fig. 842.—Same as Fig. 841. In view of probable low grade malignancy of tumor (duration, four and one-half years) excision of *humerus carried out on recurrence* defect repaired by use of upper half of fibula. Definite recurrence of tumor about graft five months post operatively Patient succumbed from metastasis in 1937 Insert shows specimen consisting of graft and remaining lower third of humerus completely *surrounded by recurrent tumor*

Resection of Upper End of Humerus With Substitution by a Fibular Graft

The following technic is rarely indicated for giant cell tumor being more suitable for tumors of low-grade malignancy

Technic.—An anterior or Henry incision five inches in length is made from the outer third of the clavicle to the insertion of the deltoid muscle. The

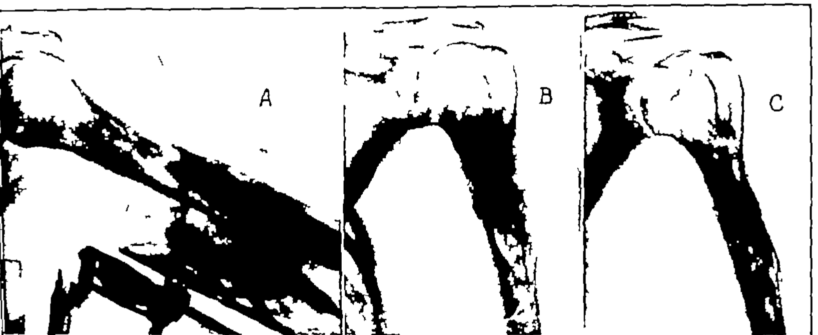


Fig. 841.—*A* Pathologic fracture of upper third of humerus treated by Dr H. W. Dierkesheide, in 1932 followed by solid union. No symptoms for two years. *B* On first examination, in January, 1934, definite soft tissue tumor found, with extensive destruction of upper portion of humerus. Biopsy revealed Ewing's tumor. *C* Marked improvement under regime of extensive roentgen therapy and Coley's toxins.

retracted to expose the growth on the undersurface. The exostosis was then removed along the wing of the scapula from its spine downward by means of bone-cutting forceps. The muscles were then reattached as follows: the subscapularis muscle was sutured at its lateral border to the teres major and to the serratus magnus at its vertebral border, leaving the sheath of the muscle between the subscapularis and the infraspinatus intact. The infraspinatus muscle was sutured to the teres minor on its axillary border, the serratus magnus on its vertebral border, and the combined attachments of these muscles were sutured to the rhomboids. *The trapezius muscle was replaced over* the rhomboids.

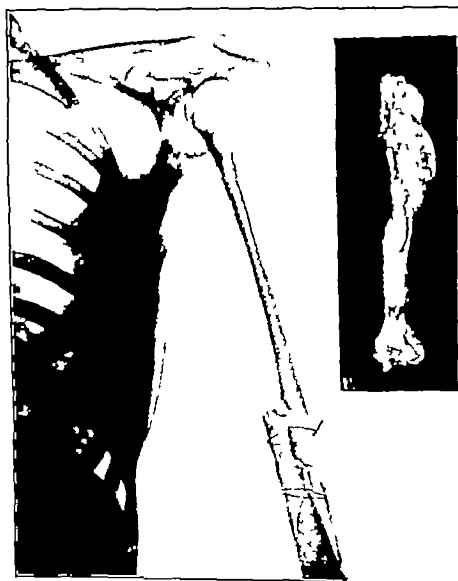


Fig. 842.—Same as Fig. 841. In view *of probable low-grade* malignancy of tumor (duration, four and one-half years), excision of humerus carried out on recurrence; defect repaired by use of upper half of fibula. Definite recurrence of tumor about graft five months postoperatively. Patient succumbed from metastasis in 1937. Insert shows specimen consisting of graft and remaining lower third of humerus completely surrounded by recurrent tumor.

Resection of Upper End of Humerus With Substitution by a Fibular Graft

The following technic is rarely indicated for giant cell tumor, being more suitable for tumors of low grade malignancy.

Technic.—An anterior or Henry incision five inches in length is made from the outer third of the clavicle to the insertion *of the deltoid muscle. The*

A





B

Fig. 843.—*A*, Giant cell tumor of distal end of radius with practically complete destruction of distal end of bone. *B*, After resection of distal end of radius and substitution by proximal end of fibula. Satisfactorily functioning wrist with good stability four months after operation.

fibers of the deltoid and pectoralis major muscles are separated longitudinally, exposing the shoulder joint and the upper one third of the humerus The capsule is incised longitudinally The muscles inserted into the lesser and greater tubercles and upper third of the humerus are detached the deltoid insertion being preserved intact if possible The biceps tendon is lifted from the bicipital groove and retracted medially The lateral head of the triceps muscle is next stripped from the posterior surface of the humerus, care being taken to protect the radial nerve With a Gigli saw, the humerus is then severed two or three inches distal to the tumor The proximal fragment is grasped with bone-holding forceps and removed with the tumor and periosteum

The upper third of the fibula is removed p 129, and a flat surface two inches in length is chiseled out on its inner aspect The lateral aspect of the humerus is similarly fashioned The fibula is then placed in the defect in a manner which allows the cartilaginous portion of the fibular head to articulate with the glenoid and the flat portions of the humerus and fibula to appose. Three screws are placed through the graft and the humerus The detached muscles are sutured only to the soft tissues.

After Treatment.—A cast is applied from the heads of the metacarpal bones over the shoulder and around the body to the iliac crest. After three months the cast is removed and physical therapy is instituted to the elbow and wrist, while some form of support as an abduction humerus splint is worn until consolidation is complete

Resection of Distal End of Radius With Substitution by a Fibular Graft

Technic.—A lateral incision four inches in length is made over the lower third of the radius (p 169) exposing the capsule of the tumor and the shaft of the radius. The latter is severed with a Gigli saw one inch above the tumor The end of the distal fragment is grasped with bone-holding forceps and the entire lower extremity of the radius, with the tumor and periosteum is removed If possible, the tumor should not be invaded if this is unavoidable however and tumor tissue is extruded recurrence is not likely The upper one-fourth of the fibula is now approached through a lateral incision (p 129) the common peroneal nerve being retracted. The shaft is exposed subperiosteally and severed four or five inches below its upper extremity The lower end of the proximal fragment is grasped with bone holding forceps, the upper portion, including the head is dissected out, and the tibiofibular joint disarticulated. The graft is next freed of all soft tissue and a flat surface two inches in length is created on its inner surface by means of a chisel (The apposing surfaces of the radius and fibular graft may be step-cut for more exact craftmanship) A similar area is then denuded and leveled on the outer aspect of the radius These raw surfaces of the fibular graft and radius are approximated and the graft is so inserted that the apex of the head of the fibula replaces the styloid process of the radius, while the articular cartilage of the anteromedial aspect of the head articulates with the scaphoid bone The flat portions of the fibula and radius are held together with screws.

After Treatment.—With the elbow at 90 degrees flexion and the forearm in mid position between pronation and supination the arm is immobilized in a plaster cast from the metacarpophalangeal joints to the upper third of the humerus. At the end of eight weeks, the cast is replaced by a leather corset brace with a movable joint at the elbow The brace is worn for a period of

three to six months. As soon as union is sufficiently solid between the graft and parent bone, physical therapy is instituted protection being continued until the graft is solidly incorporated into the shaft of the radius, as demonstrated by the roentgenogram.

Milch reports the use of a fibular graft to replace the lower end of the radius after resection for a giant cell tumor The distal end of the fibular transplant is fixed to the scaphoid bone by arthrodesis, and the proximal end is fixed to the resected shaft of the radius. *Cuff resection of the ulna* (*p 598*) was carried out to permit rotation of the forearm. Dickson reports a similar operation a tibial graft being utilized and the distal end of the ulna being resected by Darrach's technic to provide supination and pronation

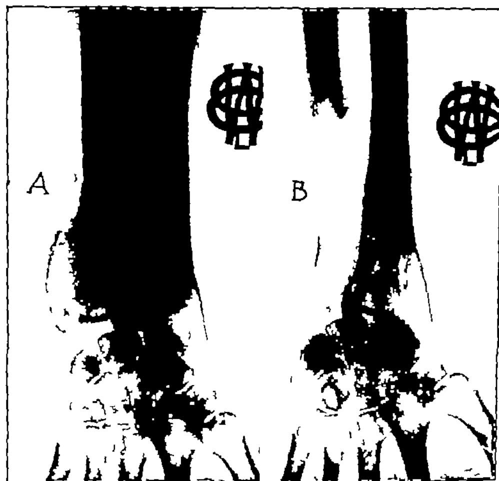


Fig. 444.—*A*, Giant cell tumor of distal end of ulna. *B* After resection of distal three inches of ulna, including tumor No recurrence; function of wrist satisfactory

Resection of Metacarpal Bone—Substitution by a Graft

Leventhal and Kirshbaum report a reconstruction of the third metacarpal bone following resection for extensive destruction of the bone by a fibroma Their procedure might also be employed following resection for other lesions, such as a giant cell tumor or traumatic defects.

Technic (Leventhal and Kirshbaum).—The metacarpal bone is exposed by a dorsal longitudinal incision The entire bone with the exception of the base, is resected with the tumor The stump of the metacarpal bone is reamed out to receive the rounded end of a tibial graft 7 by 1 by 1 centimeters. The

opposite end of the graft is rounded to conform to the contour of the articular surface of the proximal phalanx The soft tissue envelope is sutured over the graft.

In the event the base of the metacarpal bone has been destroyed this procedure might be varied by inserting the graft into the corresponding carpal bone.

After Treatment.—A cast is applied with the finger in a slightly hyper extended position or in a position which seems to best stabilize the graft. At the end of one month, the cast is removed and active and passive exercises are begun

Over a period of months the bone graft in the case reported by Leventhal and Kirshbaum underwent a metamorphosis comparable to the demands of function. Eventually the graft almost assumed the normal contour of a metacarpal bone even to reforming a head and neck, and a medullary canal.

AMPUTATION

Amputation for a giant cell tumor is indicated in the following conditions

1 When destruction of the bone from the tumor is so far advanced that treatment by the more conservative measures outlined above precludes eradication of the tumor or a functional extremity,

2. Superimposed infections which cannot be eradicated by conservative treatment

3 So-called malignant variants of a giant cell tumor

The amputations are described in Chapter XII

RECURRENT GIANT CELL TUMOR

The treatment of recurrent giant cell tumor depends entirely upon the diagnosis of the original microscopic sections by a competent bone pathologist. If, after careful scrutiny of the sections, one is still convinced that the lesion is benign, a second curettage is warranted, provided bone destruction is not too extensive or resection not feasible Following a second recurrence, if bone destruction is extensive, amputation may be advisable, particularly in the lower extremity Amputation is always indicated if the recurrence is a malig nant variant of the growth.

ANGIOMA

Angioma is an extremely rare type of bone tumor There are two vari eties the capillary and the cavernous On section the cavernous variety presents grossly the picture of an altered blood clot, while in the capillary form, the blood spaces are swollen and more circumscribed. This tumor appears to have an intracortical origin and tends to expand the cortex outwardly to the thinness of paper In the roentgenogram it presents a ' soap bubble' appearance. X ray therapy or curettage usually effects a cure

PRIMARY MALIGNANT TUMORS OF BONE

Primary malignant bone tumors vary as to the rapidity of growth and degree of malignancy In many cases the diagnosis of malignancy may be made from the clinical history physical examination, and roentgenogram on account of the similarity to many benign lesions of bone, however a microscopic examination should always be made before treatment is undertak— T-

make an accurate diagnosis of a microscopic section the pathologist must have had considerable experience in bone pathology even then, the diagnosis is not always infallible. The tissue may be obtained by needle or punch biopsy or by open operation and removal of a small portion of the tumor. Although valuable information may be secured from aspiration and punch biopsy diagnosis by these methods is not as dependable as by the open biopsy, wherein a characteristic section may be removed for study of the gross pathology. Some authorities, as Ewing seriously object to biopsy by open operation on the ground that the trauma of the operation exacerbates the growth of the tumor and causes early metastasis. Nevertheless, a high percentage of patients who have obtained a five year cure have had biopsy prior to excision of a tumor. Undoubtedly there is evidence that biopsy does cause a rapid increase in growth but in these cases the malignancy usually is of such high degree that the end result is not materially affected.

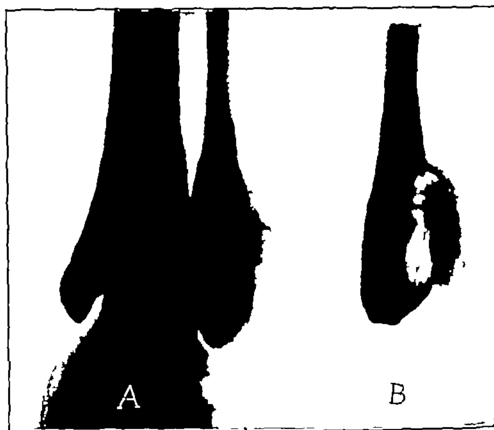


Fig. 815.—A Osteogenic sarcoma of lower end of fibula. B Roentgenogram of specimen after resection of lower third of fibula.

From an histologic study of the specimen removed at biopsy one may as a rule, determine immediately not only the nature of the tumor but, to some extent, its degree of malignancy. Malignant tumors composed primarily of mature cartilage cells carry a much better prognosis than a wild growth of a primitive character and may often be treated successfully by resection.

Information of material prognostic value may likewise be obtained from the history location of the tumor roentgenographic appearance, and response *to roentgen ray therapy. Obviously tumors which have grown slowly offer a* much better prospect of cure than those which have developed within two or

three months. Age is another factor which influences the outcome. Few children or adolescents survive a primary osteogenic sarcoma despite an early diagnosis and adequate treatment whereas a fair percentage of adults above thirty five years of age may be expected to survive. Further tumors in the distal ends of the extremities, that is, in the hands or feet carry a much better prognosis, even though apparently highly malignant than those located closer to the trunk, or those which involve the pelvis, spine or shoulder girdle.

Copeland offers the following generalizations regarding the treatment of osteogenic sarcoma: roentgen therapy alone has rarely produced a cure regardless of the type of sarcoma; resection with roentgen therapy offers a slightly better prognosis; amputation is usually the preferred treatment.

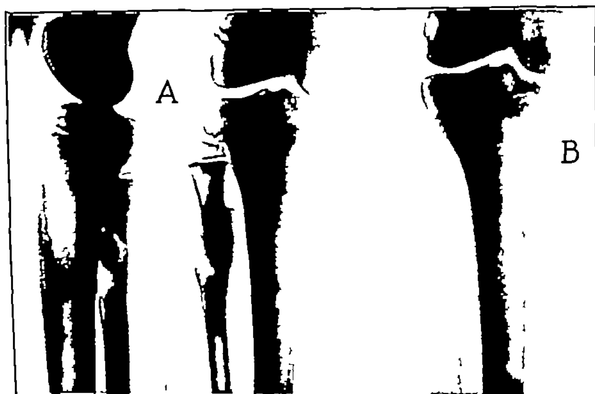


Fig 646.—A Osteogenic sarcoma of upper third of fibula in boy aged fourteen years. B Treated by resection and roentgen therapy. High thigh amputation after recurrence of tumor. Metastasis in lungs eighteen months postoperatively.

For the less aggressive malignant tumors, Coley and Phemister have emphasized the possibility of conservative surgery such as partial amputation of a hand or foot or resection. Conservative surgery is primarily applicable to borderline cartilaginous tumors in the distal end of an extremity. A study of the end results of treatment of malignancies of extremities shows that the majority of cures are obtained by radical surgery; the choice between conservative and radical surgery for a malignancy must therefore be made after more than ordinary consideration and thought; the pathologist, the surgeon, and the patient must arrive at a unanimous decision before the less radical course is undertaken.

The procedures described for giant cell tumor are applicable to the less aggressive malignancies, namely resection, resection and bone graft (p. 1179) and partial amputations of the hand and foot (Chapter XII).

When a primary malignant tumor is suspected from the history examination and roentgenogram the following procedure is employed in practically every case wherein amputation is feasible. Hemostasis by a pneumatic tourniquet lessens the danger of metastasis. If possible, a tumor of the trunk should be excised without a biopsy

Technic.—Through a small incision over the prominence of the tumor a section of tissue of adequate size for examination is removed The section should be studied for its gross characteristics, whether soft, gelatinous, semi-solid, cartilaginous with gritty particles, or of a fish flesh appearance. At times, only degenerated detritus is present, depending upon the stage of the tumor

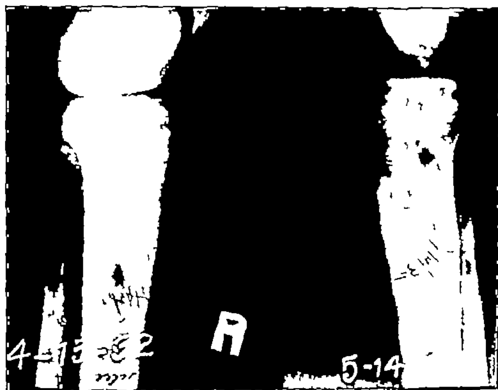


Fig. 847.—Osteogenic sarcoma, chondroblastic type, upper end of tibia. Patient first examined by interne and dismissed, as roentgenograms apparently negative. Returned in one month with definite tumor mass and beginning destruction of bone in region of condyles of tibia. Treated by low thigh amputation.

The anesthetic is continued while a microscopic examination of a frozen section is made since this requires only a few minutes. From a résumé of the microscopic report, the gross appearance of the tissue, the clinical history and examination, the roentgenographic findings, and the preoperative response to roentgen ray therapy when this has been given, an accurate diagnosis generally can be made at least one can usually determine whether the tumor is benign or malignant. When convinced of the malignancy of the specimen, amputation or complete excision is carried out before the tourniquet is removed. If, however after all the evidence has been duly considered, even a slight doubt remains as to the malignancy of the growth, the wound is closed until a permanent microscopic section can be made This may require from one to three days if decalcification of the bone is necessary otherwise a report may be secured within twenty four hours and appropriate treatment then carried out.

The impression prevails that amputation should be performed above the joint of the bone in which the tumor is found For example, if the tumor involves the tibia at the ankle the amputation should be just above the knee joint. Of twelve living patients with malignant bone tumors whose cases have been reported by the clinic seven had amputation above and five below the next proximal joint Of eighty-one five year cures of the Registry of Bone Sarcoma of the American College of Surgeons there were sixty three cases in which the site of amputation could be determined from the records, of these thirty five were above or proximal to the bone involved and twenty eight were through the affected bone above the tumor These proportions are practically identical to those found in our cases

For malignant tumors in the region of the ankle wherein growth has been slow covering a period of one or more years, amputation through the upper third of the leg may be sufficient and of course is preferable as an artificial limb at this point will be less disabling When amputation is performed through the bone in which the tumor occurs, a section should be taken from the end of the bone and examined for evidence of malignant changes if found to be invaded amputation above the joint is indicated Recurrence in an amputated bone is exceedingly rare, however whether amputation is through the affected bone or the bone above

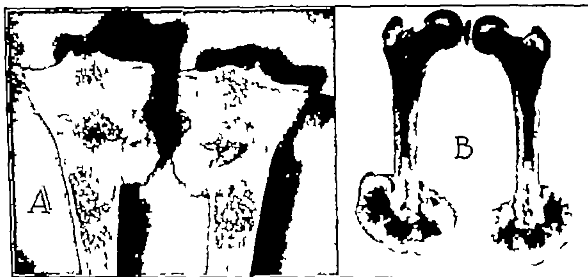


Fig. 848.—Same as Fig 847 *A* Gross specimen of tibia removed at amputation. *B* Nine months after low thigh amputation, recurrence of osteogenic sarcoma in stump, necessitating hip joint disarticulation. Patient now living and well apparently a "cure," seven years after first amputation.

When a primary malignant tumor occurs above the lower third of the bones of the leg amputation should be carried out above the knee Malignant tumors of the lower third of the femur present the same problem as those of the leg namely whether disarticulation of the hip is preferable to amputation through the upper third of the bone The technics of amputation are described in Chapter XII

Chondromyxosarcoma

As the name implies, chondromyxosarcoma is composed of cartilage myxomatous connective tissue and bone formed from malignant tumor cells. The tumor may be either primary or secondary in type The primary form appears in adolescence and early adulthood, the most common sites being the

lower end of the femur and upper end of the tibia This tumor arises at the sites where tendons are attached directly to bone. It is therefore a periosteal osteogenic sarcoma which develops insidiously and eventually invades the underlying bone causing lysis. The bone is invaded late that is, several months probably after the onset of growth at the primary site. Pain and swelling prompt the patient to seek medical aid. A roentgenogram, if taken early may show only a soft tissue shadow with cortical sclerosis beneath. After the bone has been invaded however one may observe varying degrees of bone lysis mixed with areas of osteosclerosis the latter being the tumor bone

The treatment is early amputation. Resection or excision may be attempted but too frequently it is followed by metastasis and death.

On the average the mortality rate is approximately 90 per cent

The secondary type of chondromyxosarcoma arises from some pre-existing benign lesion such as an osteoma osteochondroma old callus at the site of a healed fracture or Paget s disease Like the primary form it is composed of cartilage myxomatous connective tissue and tumor bone. Pain and swelling about one of the above otherwise asymptomatic lesions lead the patient to consult a physician

The roentgenogram may be a material aid in the diagnosis of this tumor in that a remnant of the original benign lesion from which malignant changes have developed such as a soft tissue tumor shadow or a fuzzy border about the original tumor may be demonstrated. In either of the above tumors, a biopsy should be made and the diagnosis established microscopically before a decision is made as to treatment.

Amputation is the treatment of choice Excision or resection is more hazardous. The mortality rate (75 per cent) is lower in the secondary chondromyxosarcoma than in the primary form (90 per cent)

Osteoblastic Osteogenic Sarcoma

Osteoblastic osteogenic sarcoma differs materially in one respect from other forms of bone sarcoma in that its cells are more highly differentiated This lesion has a predilection for the metaphyseal region of the lower end of the femur and the upper end of the tibia in young people of the postadolescent age It arises subperiosteally and grows both outwardly infiltrating and elevating the periosteum and inwardly altering and replacing the cortex, into the marrow and cancellous portion of the bone

Trauma, pain, and a tumor of a few weeks to a few months duration are prominent clinical features.

Microscopically this lesion consists of much tumor bone and osteoid material in disorderly arrangement and many malignant fibroblasts and osteoblasts. Single and multiple nucleated tumor giant cells are not uncommon. Hyperchromatism of the cells is a prominent feature.

The roentgenographic findings are conspicuous consisting of the presence of much spotty sclerotic material throughout the tumor with little or no evidence of lysis. As the tumor grows out from the bone spicules of tumor bone are laid down at a right angle to the long axis of the shaft, giving a sun-ray effect One may see a similar even more pronounced and clear-cut roentgen picture in some cases of endothelial myeloma (Ewing s tumor) and in cases of retinoblastoma after the latter has metastasized to bone In Ewing s tumor and retinoblastoma however the spicules of bone producing the sun

ray effect are not of tumor origin rather they are produced by the normal osteogenetic tissue cells in and about the cortex

The treatment is radical surgery, either amputation or resection the former being much the safer

The prognosis is more favorable than that of some of the other forms of osteogenic sarcoma the mortality being about 75 per cent

Chondroblastic Osteogenic Sarcoma

Chondroblastic osteogenic sarcoma is a relatively rare disease of adolescence which arises from pre-existing cartilage in the epiphyseal plate

It is composed of malignant chondroblasts with areas of calcification About the margins of the tumor, nonmalignant multinucleated giant cells may be observed serving as scavengers by removing the calcified cartilaginous particles These tumors are quite vascular

The roentgenogram reveals a periosteal motley soft tissue shadow and irregular areas of bone destruction usually on the metaphyseal side of the epiphyseal cartilage

The treatment of choice is amputation The mortality rate is approximately 90 per cent

Osteolytic Osteogenic Sarcoma

Osteolytic osteogenic sarcoma is a rapidly growing highly lytic tumor which appears to arise in the medullary cavity of the metaphyseal portion of long bones. Its lytic power is so great that the cortex seems to melt away without allowing time for expansion to take place In children and in adolescents the roentgenogram gives one the impression that an explosive had been set off inside the bone

Microscopically this tumor consists of large hyperchromatic vesicular malignant spindle cells and oval to round malignant osteoblasts, some of which appear as large cells with a sprinkling of large chromatin particles the so-called dusty cells. Epulislike giant cells may be quite numerous in the less anaplastic tumors If anaplasia is dominant, however malignant tumor giant cells predominate Atypical mitotic figures are numerous. More or less osteoid is usually present

This tumor may appear at any age The older the patient, the less active is the growth and the more spindly are the cellular elements.

The treatment is amputation The mortality is almost 100 per cent in patients in the first two decades of life In older patients, the prognosis is less fatal.

PRIMARY NONOSTEOGENIC TUMORS

Primary nonosteogenic tumors of bone with the exception of benign angiomata are malignant. These include endothelial myeloma (Ewing s tumor) fibrosarcoma neurogenic sarcoma and multiple myeloma The most common of these tumors is the endothelial myeloma or Ewing s tumor The consensus is that the majority of Ewing s tumors involve the shafts of long bones, particularly the tibia femur humerus, or fibula In an analysis of 18 cases in our clinic however the shafts of the above long bones were involved in nine and in the other nine, the lesions were about equally distributed between the upper and lower metaphyses. In addition to these 18 cases, there were 11 others in the whole series, located as follows ilium 3 ribs, 3 mandible 2 pubis 1 calcaneus, 1 and sacrum 1

Ewing's tumor is one of the most deceptive of all of the primary bone tumors. Because of its insidious nature and its clinical and roentgenographic features, such as attacks of fever with an elevated leucocyte count, suggesting an inflammatory process, it is not infrequently mistaken for osteomyelitis. This is especially true if the tumor arises in the metaphysis, and is observed after the stage of sclerosis has been passed. If on the other hand, the tumor involves the shaft and is observed fairly early, one may see either sclerosis of the adjacent cortex or an oval extra-cortical soft tissue tumor with the classical sun ray effect as a result of the periosteum having been raised by the tumor and spicules of bone having been laid down by the osteogenetic cells along the course of blood vessels of the Volkmann canals. This is not tumor bone, but, rather normal reactive bone in contrast to the malignant tumor bone formed in osteoblastic osteogenic sarcoma. We have seen patients who had been operated on repeatedly under the mistaken diagnosis of osteomyelitis. One should always obtain a biopsy and confirm the diagnosis with the microscope when possible before outlining a course of treatment. If for any reason a microscopic examination cannot be made one may resort to a so-called therapeutic test with roentgen therapy if the tumor is an endothelial myeloma regression may quickly follow

The curative effect of irradiation alone upon endothelial myeloma is doubtful no matter how accessible the tumor The only patients in our series who have survived ten years and over had, in addition to irradiation amputation of the affected limb (with one exception) and Coley's toxin. The efficacy of the toxin is at present still in doubt.

Fibrosarcoma may arise in the outer layers of the periosteum or adjacent structures such as the fascia or tendon. A true fibrosarcoma never arises within bone itself When bone is involved it is always from without by continuity of growth. Because of some similarity of the malignant fibroblast in each, this type of malignancy has been confused with osteolytic osteogenic sarcoma Anaplasia is present to a pronounced degree in the osteogenic sarcoma, in contrast to the more orderly growth of the cells in fibrosarcoma. If the patient is examined early one may expect to find much more extra osseous soft tissue tumor than the amount of bone involved A tumor of this type which arises near a joint as it usually does, is prone to invade the adjacent joint, as well as the bone by continuous growth

Neurogenic sarcoma may grow in a fashion similar to that of fibrosarcoma and may thus cloud the diagnosis no little One must rely upon the microscopic examination for the diagnosis of these neoplasms.

Resection or excision of a fibrosarcoma or a neurogenic sarcoma is generally unwise even though situated in a bone like the fibula ' It is far wiser to sacrifice a limb than a life The mortality rate will depend upon how early the diagnosis is made and how radical surgical treatment is carried Irradiation therapy is of little if any value in these cases.

The so-called oat-shaped cell fibrosarcoma which not infrequently arises from the soft tissue structures of the feet, deserve special mention This neoplasm although highly cellular and having a scant intercellular stroma, tends to grow slowly and metastasize late Here, again local excision usually fails, though an attempt at removal of such a tumor is not fraught with as great a hazard as is excision of other types of fibrosarcomata, as discussed in the preceding paragraphs. We have had patients survive following amputation who previously had been subjected to two or three attempts at local removal of the

tumor The treatment of choice is amputation of the affected part. In contrast to other types of sarcoma related to bone the mortality would be low if the affected part were amputated early in the course of the disease

Multiple myeloma as the name implies usually involves practically the whole skeleton and especially the ribs vertebrae, pelvic bones and skull by the time the symptoms cause the patient to seek medical opinion The tumor is rarely seen in patients under 50 *years of age* The tumor cell is a plasma like cell having a pyknotic eccentric nucleus and much cytoplasm

The symptoms may be rheumatic in nature or neurological, such as radiculitis or paraplegia Pathologic fractures are prone to occur though they usually heal Twenty or more pathologic fractures have been known to take place in a single patient. Bence-Jones albumin may be found in less than 50 per cent of cases.

Roentgenologically, the tumors are intramedullary and appear as punched out areas varying from a few millimeters to several centimeters in diameter They do not expand the cortex

There is no known cure for the disease though these patients may live several years after the diagnosis is made Irradiation may be employed as a palliative measure for the relief of pain

METASTATIC TUMORS OF BONE

Metastatic tumors, such as carcinoma lymphosarcoma and hypernephroma are all malignant. Occasionally isolated lesions in bone are observed which resemble metastatic tumors, yet no primary distant growth can be found In such cases, biopsy is indicated to establish a diagnosis. Even though the diagnosis of a metastatic growth is established however amputation is rarely indicated other than for the relief of pain or in the presence of a pathologic fracture. Roentgen therapy while not curative *may keep the local tumor under* control for a long period of time thereby preserving some function of the part, and providing considerable relief of pain

TUMORS OF JOINTS

Tumors may arise primarily from the structures within the joints or may invade the joint from extra articular tissues.

Benign or malignant neoplasms of joints, although uncommon are observed most often in the knee. The symptoms may be those of an internal derangement or of a low-grade arthritis with proliferation of the synovial lining On examination, the tumor may be palpated either as a localized, well-defined mass, or as a diffuse mass occupying the entire joint. Tumefaction, pain, and disability are sufficient to warrant exploration and biopsy to determine the true nature of the lesion. Roentgenograms are of no value in the diagnosis.

Synovioma, which arises primarily from the synovial lining, is the most common of the malignant tumors of joints. The diagnosis is seldom made except by biopsy Haagensen and Stout, after reviewing the results of 104 reported cases of synovial sarcoma, advised a carefully limited biopsy for diagnosis followed immediately by a high *amputation*. The fact that this lesion remains localized for some time leads to an erroneous idea that less conservative measures may be adequate. The prognosis is grave

The benign tumors, which are of higher incidence, are lipoma, hemangioma, *fibroma, xanthoma,* and *endothelioma.* [Synovial osteochondromata or osteo-

chondromatosis is regarded as a tumor by some authors In this volume, however, the lesion is described in the discussion of internal derangements of the knee joint (p 274)]

The operative treatment of benign tumors of the joints consists of wide resection of the tumor Lipoma and fibroma usually are localized, and wide exposure of the joint is therefore unnecessary

For a cavernous hemangioma of a joint, surgical excision is adequate provided the lesion is localized or pedunculated Bennett and Cobey advise x ray therapy for diffuse lesions which lead from a joint into the adjacent muscles or into bones since in these, excision is neither feasible nor practicable

DeSanto and Wilson reviewed the literature on xanthomatous tumors of joints, and added some cases of their own They noted that xanthomata originate in chronic hemorrhagic villous arthritis and may be solitary or multiple. For the solitary tumors local excision is adequate for multiple or diffuse xanthomata synovectomy (p 839) effects a cure

The prognosis of excision of circumscribed tumors is excellent, and full function usually may be restored When complete synovectomy is required, not more than 50 per cent of normal motion may be expected as the procedure is necessarily mutilating

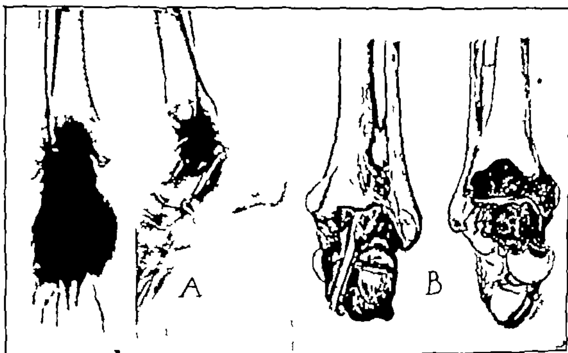


Fig 849 — Xanthoma of ankle joint. A Roentgenogram showing irregular punched out defects in astragalus and tibia. True nature of lesion diagnosed at operation. Tumor involved not only ankle joint, but extended throughout tarsus and up the leg. Destruction so extensive that amputation was performed. B Drawing of specimen.

TUMORS OF THE SOFT TISSUES

Tumors of the soft tissues vary widely in incidence, etiology histology and location. From a surgical standpoint, however they are of only two types benign and malignant. An exploration is warranted in the presence of any unusual mass in the soft tissues, as in many cases the true nature of the growth cannot be determined until sections are studied microscopically with a number of stains.

The common *benign soft tissue tumors* are fibroma, neurofibroma, lipoma osteochondroma giant cell tumor, xanthoma hemangioma, and lymphangioma The common malignant tumors are fibrosarcoma and epithelioma. Both benign and malignant types may arise in the skin, subcutaneous tissues, tendons, tendon sheaths, fasciae, vessels, or nerves.

No single surgical technic can be described for the removal of these tumors each presents an individual problem As a rule the benign tumors are well encapsulated and may be removed in toto Since the growth may involve or may be adjacent to important vessels or nerves, the approach should conform to anatomic planes. Frequently the incisions utilized in surgery on the osseous structures (Chapter IV) are suitable One should exercise every precaution to avoid incision of the tumor during removal. If the growth is benign and is thoroughly resected usually there will be no recurrence

At the present time there is a tendency to undue conservatism in the treatment of malignant tumors of the soft tissues that is, the tumor is excised and amputation is deferred until one or more recurrences take place. This course may be justified in some cases, as often even after a careful study of permanent sections, distinction between a benign and malignant neoplasm is difficult as, for example between benign fibroma and fibrosarcoma. Further complete excision of a less malignant tumor may result in a permanent cure When, on gross examination however an infiltrating tumor is found to be unquestionably malignant amputation should be performed immediately despite the possibility of a cure by roentgen ray therapy and excision

Prior to operation on any tumor which is suspicious of malignancy roentgenograms should be made of the lungs, as this is the most common site of metastases. If metastases are present only palliative treatment is indicated Preoperative roentgen ray therapy is of little practical value as the diagnosis of malignancy is seldom established until a biopsy is made Postoperative roentgen ray therapy is advocated by some surgeons.

The following case reports amply illustrate the principles of treatment

Case I.—A girl, aged thirteen years was found to have a fluctuant tumor mass just above the external epicondyle of the humerus, apparently in the brachioradialis muscle. The tumor was oval in shape, measuring two inches in length and one inch or more in width. Only slight pain of an intermittent character was present.

The skin and fascia over the tumor were incised for three inches, beginning just above the external condyle of the humerus and extending downward on the lateral aspect of the forearm. The upper third of the brachioradialis muscle was involved in a dark mass, rather mottled in appearance. Examination of the gross specimen revealed a large number of hemorrhagic areas interspersed through a glistening pearly-gray fibrous connective tissue with scattered areas of yellow tissue. Microscopic study demonstrated numerous enlarged capillaries. The diagnosis was capillary hemangioma. The entire tumor together with the upper three inches of the brachioradialis muscle, was excised the distal end of this muscle was sutured into the extensor carpi radialis longus muscle.

Convalescence was without incident, and function of the arm apparently was not affected. There has been no recurrence

Case II.—A girl, aged twenty nine years, sought examination on account of a mass on the calf of her left leg The mass was found to be the size of a hen s egg and of fish flesh appearance and rubber like consistency Roentgenograms of the lungs were negative

A long incision was made over the tumor the deep fascia was incised, and the fibers of the gastrocnemius muscle were separated. Deep to the soleus muscle an encapsulated mass three inches in length and two inches in width was exposed. Apparently the mass was not adherent to the deep fascia and did not arise from any particular source. Excision was readily accomplished and recovery was uneventful. Microscopic section showed a fibrosarcoma of low grade malignancy The patient was given roentgen ray therapy

After sixteen months the patient returned, and a recurrence smaller than the original tumor was found in the same location. Roentgenograms of the lungs at this time also were

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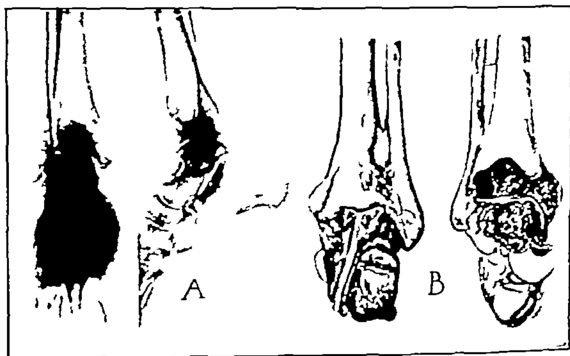


Fig. 819—Xanthoma of ankle joint. *A* Roentgenogram showing irregular punched out defects in astragalus and tibia. True nature of lesion diagnosed at operation. Tumor involved not only ankle joint, but extended throughout tarsus and up the leg. Destruction so extensive that amputation was performed. *B* Drawing of specimen.

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After sixteen months the patient returned, and a recurrence, smaller than the original tumor was found in the same location. Roentgenograms of the lungs at this time also

These cases demonstrate the fact that malignant tumors of the soft parts carry a grave prognosis In our experience, conservative treatment adds to the seriousness of the condition Although by no means a guarantee of cure, amputation at the earliest sign of the tumor might serve to reduce mortality to an appreciable extent

Xanthoma of the Tendo Achillis

Friedman reports two cases of xanthoma of the Achilles tendon, wherein he resected the major portion of the tendon leaving only a thin strip The plantar flexion weakness gradually disappeared as the resected tendons were replaced by thick scar tissue and the posterior tibial muscles and peronei increased in power In the second case the greater part of the tendon was cut away in the frontal plane, so that the remainder approached the normal size of the tendon.

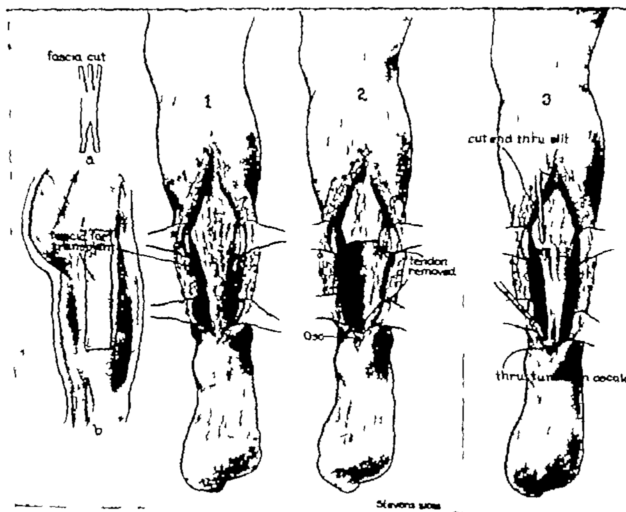


Fig 861.—1 Xanthoma of tendo Achillis 2 Diseased portion of tendon resected 3 Defect repaired by strips of fascia lata anchored proximally through the muscle and distally through a tunnel in os calcis. (From Young, F and Harris C. T Surg Gynec. & Obst. 61, 662, 1935.)

Young and Harris report a case of bilateral giant cell xanthoma wherein the tendo achillis hypertrophied bilaterally to an extreme degree Although the size of the tendon was reduced by removal of a longitudinal wedge relief was incomplete. Roentgen therapy was of no avail. The two tendo achilles were enlarged approximately three times their normal size by tender

negative. Again the tumor was excised, as amputation above the knee in a healthy and beautiful young girl should be deferred so long as there is a possibility of cure by other means. Postoperative roentgen ray treatment was given both to the site of the lesion and to the lungs. A few months later a third and much larger tumor had developed, accompanied by extensive metastases in the lungs. There were no clinical symptoms. Death occurred three and one-half years after the appearance of the growth.

CASE III.—This patient, a woman, aged thirty-five years three months earlier had discovered a mass at the junction of the middle and upper thirds of the anterior aspect of the thigh. Growth had progressed rapidly and at examination a tumor four inches in length and two inches in width could be palpated over the rectus femoris muscle.

A longitudinal incision six inches in length was made over the anterior aspect of the thigh, through the skin and fascia down to the rectus femoris muscle. The tumor apparently was confined to this structure, but was so extensive that complete removal of the muscle was considered advisable. The incision was therefore extended upward to within one inch above the anterior superior spine on the crest of the ilium, and downward to the patella. The origin of the rectus femoris muscle was exposed and severed together with a small attachment of bone from the anterior inferior spine. The muscle was then separated from the vasti muscles down to the patella, severed at this point, and delivered in toto. Microscopically the growth was cellular and resembled a Ewing's tumor being composed of numerous round and polyhedral cells. The diagnosis was fibrosarcoma, primitive type, and the prognosis was regarded as poor.

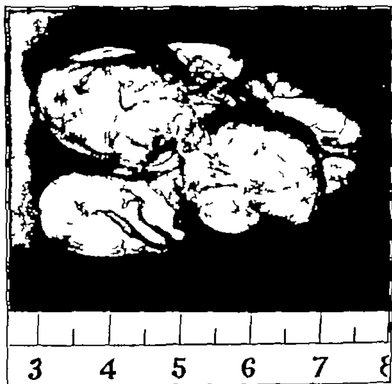


Fig. 869.—Benign fibroma removed from arm of child three years of age. Tumor well encapsulated; no recurrence.

Postoperative roentgen ray therapy was given. After two months the patient returned, complaining of some enlargement of the thigh, though not a definite tumor. On examination, the area appeared indurated, as in a chronic inflammatory reaction.

The region was explored and a mass, resembling indurated scar tissue and containing many small dark areas which were thought to be hemorrhagic, was found. The scar tissue was distributed over the region formerly occupied by the rectus femoris muscle. A biopsy was taken, and frozen section revealed only chronic inflammatory tissue; the wound was therefore closed. A permanent section however demonstrated that the dark areas represented a recurrence of the original tumor. The operation had been carried out with the idea of amputating if malignancy were found, yet at this time the patient declined amputation. She died of metastases a few months later.

These cases demonstrate the fact that malignant tumors of the soft parts carry a grave prognosis. In our experience conservative treatment adds to the seriousness of the condition. Although by no means a guarantee of cure, amputation at the earliest sign of the tumor might serve to reduce mortality to an appreciable extent.

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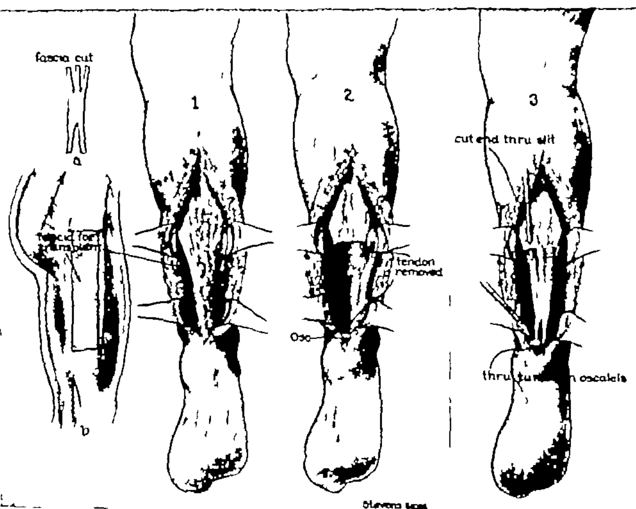


Fig. 851.—1 Xanthoma of tendo Achillis. 2 Diseased portion of tendon resected. 3 Defect repaired by strips of fascia lata anchored proximally through the muscle and distally through a tunnel in os calcis. (From Young, F. and Harris, C. T.: Surg. Gynec. & Obst. 61: 662, 1935.)

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indurated nodules. Disability was so extreme that both tendo achilles were excised and replaced by fascial grafts.

Technic (Young and Harris).—Through a longitudinal dorsolateral incision the tendo achillis was excised from its calcaneal insertion to within 8 cm of the musculotendinous junction. A strip of fascia lata 6 by 20 cm. was removed from the thigh. One end of the strip was split to form three fingerlike processes these were sutured separately into the gastrocnemius muscle The distal end of the graft was split into two processes and passed through a hole drilled in the os calcis.

After Treatment.—A boot cast was applied with the foot in marked equinus and maintained intact for a period of one month At that time the transplant felt and functioned like a normal Achilles tendon with a range of about ten degrees active flexion-extension in the ankle The equinus deformity was gradually overcome Subsequently a similar procedure was carried out on the opposite tendo achillis Eight months postoperatively the patient could walk with only a slight limp A normal range of motion was regained in both ankles though only a fair power of plantar flexion.

NEUROFIBROMATOSIS—(VON RECKLINGHAUSEN'S DISEASE)

Neurofibromatosis, or von Recklinghausen's disease, is an affection of the nervous system characterized chiefly by multiple soft tissue tumors distributed along the courses of the peripheral nerves, and pigmentations of the skin, and frequently by elephantiasis, changes in the structure of the bones, and skeletal deformities. The disease is congenital, probably arising from a disturbance of the specific elements of the nervous system early in embryonic development. Congenital and developmental anomalies, as glaucoma deafness, spina bifida, meningocele, and mental deficiency may be associated Evidence of any abnormality may be lacking at birth however and in fact may not appear until the passage of several years, or even until late in life. A strong familial tendency is also characteristic, cases having been observed in several consecutive generations

The tumors usually involve the peripheral nerves, both superficial and deep apparently however they may also develop in any of the cranial spinal, or sympathetic nerves. The actual lesion is a proliferation of the endoneurium with hyperplastic changes in the perineurium. The pathologic process in bone, according to the classical description of Brooks and Lehman begins with the development of a neurofibroma of a periosteal nerve a reaction is incited, and bone destruction and regeneration follow If during the growth of the tumor the osteogenetic element of the periosteum covers the tumor the roentgenographic picture of a subperiosteal bone cyst is produced. When the tumor invades the shaft of a long bone, and particularly if associated with hyperplasia of the lymphatics, the entire bone becomes porous and plastic and grows to an abnormal length Or on the other hand, if the tumor destroys the epiphysis, growth of the bone is retarded. The roentgenogram may show an increased dimension, abnormal contour or angulation, as well as variations in length. Occasionally pathologic fracture and pseudoarthrosis ensue.

A peculiar feature of those cases wherein the long bones increase in length is that this excessive growth may be limited to the bone or bones of a single region for example, when the tibia and fibula are affected and grow to an abnormal length, the femur may remain normal and vice versa Frequently

associated with the excessive growth of the bone, moreover, is a hypertrophy of the surrounding soft tissues or elephantiasis This complication usually develops during the more advanced stages of the disease.

Another deformity commonly observed is kyphoscoliosis, the apex of the kyphos usually being at the lower portion of the dorsal segment of the spine In addition to the local cystic formations, the pathologic changes in the vertebrae may consist of a generalized osteoporosis, erosion of the vertebral bodies from pressure, and widening of the intervertebral foramina Brooks and Lehman explain the high incidence of scoliosis by the fact that there is a close association of the vertebrae with the peripheral nerves. Weber is of the opinion that neurofibromata of the roots of the spinal nerves might in some cases be the cause of the curvature Miller suggests that the deformity of the spine may be one manifestation of a generalized congenital disturbance of which the neurofibromatosis is the most constant feature

Conservative treatment of neurofibromatosis has been found practically worthless. Excision is the only effective means of eradication of the tumors but should be undertaken cautiously since these individuals are subject to hemorrhage and shock Care should be taken also to remove the growths in their entirety otherwise, remaining remnants may undergo malignant degeneration The treatment of the skeletal deformities must be governed by the requirements of the individual case. Variations in length may be corrected as described in the sections on Asymmetrical Development (p 1556) and Inequality in Length of the Lower Extremities (p 1426)

References

Bennett G A: Malignant Neoplasms Originating in Synovial Tissues (Synoviomata) A Study of Thirty Two Specimens Registered at the Army Institute of Pathology During the War Time Period, 1941 1945 J Bone & Joint Surg 29 259 1947

Bennett G E., and Cobey M C.: Hemangioma of Joints. Report of Five Cases, Arch. Surg. 38 48 1939

Brooks, Barney, and Lehman Edwin P: The Bone Changes in Recklinghausen s Neurofibromatosis, Surg Gynec. Obst. 38 587 1924.

Campbell Willis C. Osteogenic Sarcoma, With Report of Cases, Am. J Surg 20 575 1933

— Endothelial Myeloma. An Analysis of Cases, J Bone & Joint Surg 16 761, 1934

— An Analysis of Living Patients With Primary Malignant Bone Tumors, J A. M A 105 1496 1935

— Osteogenic Sarcoma, J Bone & Joint Surg 17 827 1935.

Carrell, W B. Transplantation of the Fibula in the Same Leg J Bone & Joint Surg. 20 627 1938

Carrell W B: Scapulectomy Discussion of E. W Ryerson s Paper J A. M. A. 113 1953 1939

Cobey M. C.: Hemangioma of Joints Arch. Surg 46 465 1943.

Codman, E. A. The Shoulder Boston Mass., 1934.

Coley B. L. Conservative Surgery in Tumors of Bone South. Surgeon 10 3,9 1941

Coley B. L., and Pierson J C.: Synovioma Report of 15 Cases With Review of Literature Surgery 1 113 1937

Copeland, M M: Bone Tumors With Reference to Their Treatment Surgery 11 430 1942.

De Santo D A., and Wilson P D Xanthomatous Tumors of Joints, J Bone & Joint Surg 21 531 1939

Dickson, J A.: The Treatment of Giant Cell Tumors of the Radius, S. Clin. North America 19 1311, 1939

Ewing J: Neoplastic Diseases, ed. 3, Philadelphia, 1928, W B Saunders Co.

Friedman M S: Xanthoma of the Achilles Tendon, J Bone & Joint Surg 29 160 104

Geschickter C F., and Copeland M. M.: Recurrent and So-Called Metastatic Giant Cell Tumor, Arch Surg 20 713, 1930.

— Tumors of Bone New York 1931, Am. J Cancer

Ghormley R. K., and Dockerty M. B. Cystic Myxomatous Tumors About the Knee: Their Relation to Cysts of the Menisci, J Bone & Joint Surg 25 306 1943.

Ghormley, R. K., Henderson M S., and Lipscomb P R.: Interinnomino-Abdominal Amputation for Chondrosarcoma and Extensive Chondroma; Report of Two Cases Proc. Staff Meet., Mayo Clin. 19 193 1944.

Ghormley R. K., Myerding H. W., Mussey R. D., Jr., and Luckey C. A.: Osteochondromata of the Pelvic Bones, J Bone & Joint Surg 28 40 1940.

Gurd F B.: Surplus Parts of the Skeleton; A Recommendation for the Excision of Certain Portions as a Means of Shortening the Period of Disability Following Trauma Am. J Surg 74 70 194

Haagensen, C. D., and Stout A. P: Synovial Sarcoma Ann. Surg. 120 826, 1944.

Haggart G E. The Treatment of Primary Malignant Bone Tumors of the Humerus S. Clin North America 27 717, 1947

Hamilton, J F: Osteoid Osteoma, With Case Reports, Surg. Gynec. Obst. 81 46, 1945.

Inclan, A: Giant Cell Tumor of the Patella, Imp Seoane y Fernandez, Compostela 135, Habana Cuba.

—: Osteitis Fibrosa Localizada, Cir ortop y traumatol. 1 53 1933

Jaffe H L.: Osteoid Osteoma of Bone Radiology 45 319 1945.

Jaffe, H. L.: ' Osteoid-Osteoma '; A Benign Osteoblastic Tumor Composed of Osteoid and Atypical Bone Arch. Surg 31 709 1935.

Jaffe, H. L., and Lichenstein L. Osteoid-Osteoma Further Experience With This Benign Tumor of Bone With Special Reference to Cases Showing the Lesion in Relation to Shaft Cortices and Commonly Misclassified as Instances of Sclerosing Non Suppurative Osteomyelitis or Cortical Bone Abscess, J Bone & Joint Surg 22 645 1940.

Kleinberg S.: Oteoid Osteoma of the Femur Report of a Case Am. J Surg 53 168, 1941

Kolodny, A.: Diagnosis and Prognosis of Bone Sarcoma, J Bone & Joint Surg. 7 911 1925

—: Bone Sarcoma The Primary Malignant Tumors of Bone and the Giant-Cell Tumor Chicago 1927 Surgical Publishing Co.

Leader Sidney D., and Grand, Milton J H.: Von Recklinghausen s Disease in Children J Pediat. 1 754 1932.

Levin, O L.: Recklinghausen s Disease: Its Relation to the Endocrine System Arch. Dermat. & Syph. 4 303 1921

Levinthal, D H., and Kirshbaum, J D: Fibroma of the Middle Metacarpal Bone Resection and Reconstruction Surg., Gynec & Obst 68 936, 1939

Meyerding H. W: Roentgen Ray Therapy of Bone Tumors J Bone & Joint Surg 18 617 1936.

— *Treatment of Benign Giant-Cell Tumors J Bone & Joint Surg 18 823, 1936.*

Meyerding H. W: The Results of Treatment of Osteogenic Sarcoma, J Bone & Joint Surg 20 933 1938.

Meyerding H. W Treatment of Benign Giant-Cell Tumors by Resection, or Excision and Bone-Grafting J Bone & Joint Surg 27 196, 1945.

Milch Henry: Partial Resection of the Ischium. The Operative Procedure, J Bone & Joint Surg. 17 166, 1935

Milch H. Forearm Reconstruction Following Partial Resection of Radius, Bull. Hosp. Joint Dis. 3 100 1942

Miller Alexander: Neurofibromatosis, With Reference to Skeletal Changes, Compression Myelitis and Malignant Degeneration Arch. Surg 32 109, 1936.

Miltner L. J., and Wan F E. Giant-Cell Tumor of the Os Calcis, J Bone & Joint Surg. 14 406 1932

O Donoghue D H *A Case of Xanthoma of the Knee Joint, J Bone & Joint Surg 24* 940, 1942.

Phelps, W M: A Method of Resection of the Infraspinous Portion of the Scapula Without Impairment of Shoulder Muscle Function Yale J Biol. & Med. 2: 39 1929.

Phemister D B. Conservative Surgery in the Treatment of Bone Tumors, Surg Gynec. Obst. 70 355 1940

Phemister D B. Rapid Repair of Defect of Femur by Massive Bone Grafts After Resection for Tumors, Surg Gynec. Obst. 81 120 1945.

Platt, H. Survival in Bone Sarcoma J Bone & Joint Surg 29 6 1947

Preiser S. A and Davenport, C B. Multiple Neurofibromatosis (von Recklinghausen s Disease) and Its Inheritance Am J M. Sc 156 507 1918.

Von Recklinghausen, F: Ueber die multiplen Fibrome der Haut und ihre Beziehung zu den multiplen Neuromen Berlin, 1882 A. Hirschwald.

Rhoads, C. P., and Van Wagenen W P: Observations on the Histology of the Tumors of the Nervus Acusticus, Am. J Path. 4 145 1928.

Ryerson E. W: Excision of the Scapula Report of Case With Excellent Functional Result, J A. M. A 113 1958 1939

Scaglietti, O., and Mondolfo S Sulla varieta xantomatosa dei tumori gigantocellulari, Chir d. org di movimento 23: 435 1938

Schauffler R. McE. Transplant of the Upper Extremity of the Fibula to Replace the Upper Extremity of the Humerus, J Bone & Joint Surg 8: 723, 1926.
Schmidt, J E.: Plastic Surgery of the Os Calcis. Thirty-Second Report of Progress in Orthopedic Surgery, p 72. (Abst from Arch f klin Chir 14 No 2, 19-0)
Sharpe, John C., and Young Richard H: Recklinghausen's Neurofibromatosis: Clinical Manifestations in Thirty-One Cases Arch. Int Med. 59: 299 1937
Wallace G T., and Ghormley R K: Cavernous Hemangioma of the Knee, Proc. Staff Meet., Mayo Clin. 18 177, 1943.
Weber, F Parkes: Periosteal Neurofibromatosis, With a Short Consideration of the Whole Subject of Neurofibromatosis Quart J Med 23 151, 1929-30
Young F., and Harris C. T: Complete Excision and Reconstruction of Both Achilles Tendons for Giant Cell Xanthoma, Surg Gynec Obst 61 66 1935

CHAPTER XX

AFFECTIONS OF MUSCLES, TENDONS AND TENDON SHEATHS

Operative measures on muscles, tendons, or tendon sheaths are carried out for the following conditions acute pyogenic infections of muscles, ischemic myositis (Volkmann's paralysis) local myositis ossificans, interstitial ossification and ossifying hematoma rupture of muscles and tendons, displacement of muscles and tendons, stenosis of tendon sheaths, muscle hernia, tennis elbow ganglion and trigger finger The operations of tenodesis and tendon transference are described in Chapters XXII and XXIII

PRIMARY PYOGENIC INFECTIONS OF MUSCLE

Acute pyogenic infection may involve any muscle in the body, causing a diffuse inflammation and terminating in the localization of purulent material. The process, however is generally observed in the triceps surae (gastrocnemius and soleus muscles) or the gastrocnemius muscle alone and even here is exceedingly rare. Contracture of the muscle or muscles develops and unless prevented by splinting the tendo achillis becomes commensurately shortened, leading to an equinus deformity Before operation is undertaken antibiotic therapy is given and hot packs are applied to the area until the infection becomes localized and a circumscribed fluctuant mass is palpable. After operation antibiotic treatment is continued

Technic.—The muscle is exposed through a longitudinal incision and the fibers are split down to the abscess cavity Drainage is effected by a vaseline gauze loosely packed into the cavity or a large rubber tube inserted and fixed into the wound by a silkworm gut suture. Sutures of silkworm gut are also used to close the skin incision at each end sufficient space being left open for drainage

After Treatment.—The foot is held at a right angle to the leg by a posterior foot and ankle splint which extends from the toes to just below the knee, or by an anterior molded plaster splint from the toes to a point below the knee The latter is held in position by adhesive strips or web straps around the forefoot and leg above and below the incision. Although the desired position is more difficult to maintain by the anterior splint, daily dressings can be carried out without disturbing fixation

Walking on crutches permitted as soon as [...] symptoms subside, which may require a[...] more. When gra[...] the wound is al[...] most complete a lim[...] ankle brace (p[...] ted to be retained for a period of two m[...] til there is no [...] ncy to contrac- ture of the muscle an[...] chillis. A n[...] worn to maintain the desired position of [...] ight until t[...] actively [...] lex the foot to a normal [...] after treatm[...] imp[...] if not faithfully followed [...] ntracture [...] ly [...] mmatory les[...] and t[...] d t [...] ly [...] ction from [...] cons[...]

Contractures of the tendo achillis and quadriceps tendon are perhaps the most disabling of these complications, necessitating operative measures such as Z-plastic lengthening (pp 1021 1024)

ISCHEMIC MYOSITIS

Ischemic myositis or Volkmann's paralysis is a progressive degeneration of muscle fibers from obstruction of the circulation to an extremity Because of the lack of oxygen supply to the sensory and motor nerve plate endings, the sensory and motor paralysis develops rapidly The obstruction to the circulation arises from local arterial spasm and an associated reflex spasm of the

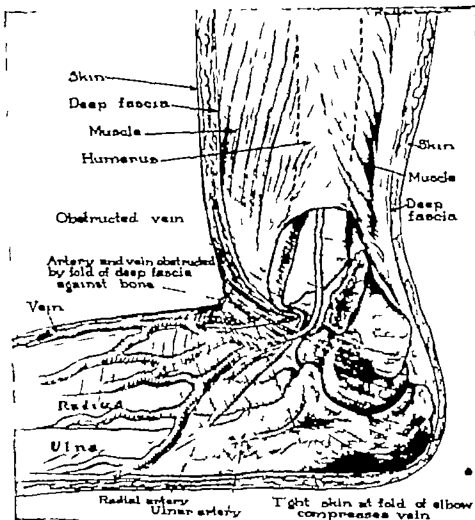


Fig 832.—Mechanism of Volkmann's contracture from unreduced supracondylar fracture of humerus. Posterior displacement of distal fragment causes kinking of brachial artery and veins with swelling about flexed elbow *skin is drawn tightly* across antecubital space, blocking venous return through superficial veins. With swelling in closed compartment of deep fascia, blood cannot circulate in this compartment. (From Bunnell, S. Surgery of the Hand, Philadelphia, 1944, J B. Lippincott Co.)

vessels which form the collateral circulation. The condition may be induced by direct trauma to the artery or by extensive trauma of the soft tissues about the artery Impairment of circulation particularly venous return may follow the use of a constricting apparatus, or the deep fascia may act as the constricting element for the deep veins Fibrous tissue replaces the muscles and a characteristic paralysis and deformity result. In the majority of cases the

muscles of the forearm principally those on the flexor and ulnar surfaces, are involved. Rarely the lesion is observed in the lower extremity

The circulation may be impaired regardless of whether or not the arm is immobilized in splints or other apparatus. Even though apparatus is properly applied, swelling may take place subsequently leading to pressure and consequent interference with the circulation The median or ulnar nerve may be injured by pressure of contracted scar tissue, or may be severed at the fracture site. Nerve injuries, if present, must be treated separately as described in Chapter XI

Fasciotomy for Impending Ischemic Paralysis

Surgery occasionally is of value in the prophylaxis of Volkmann's contracture Following supracondylar fracture of the humerus tense swelling may develop about the elbow especially in the antecubital fossa with begin-

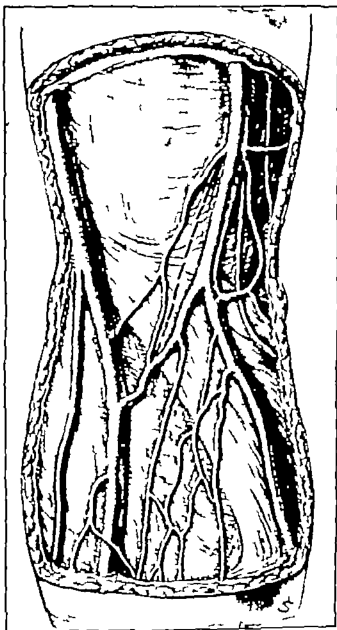


Fig. 851.—Fasciotomy for impending ischemic paralysis. Relationship of line of incision to superficial veins and deep structures.

ning loss of sensation and obliteration of the radial pulse If these signs progress after removal of all apparatus and elevation of the arm the surgeon should consider first blocking of the sympathetic ganglion to break the sympathetic reflex arc in an effort to relieve the arterial spasm If the upper extremity is involved one may block the cervical ganglion if the lower extremity is involved the lumbar sympatheetic plexus is blocked If the circu

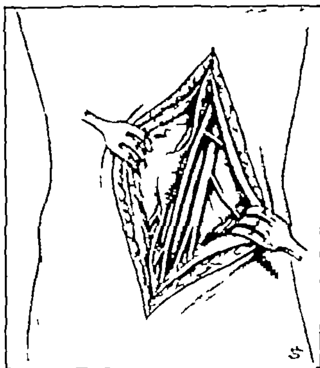


Fig. 854—After incision of brachial, bicipital, and antebrachial fasciae the median nerve and the vessels are exposed and examined for injury

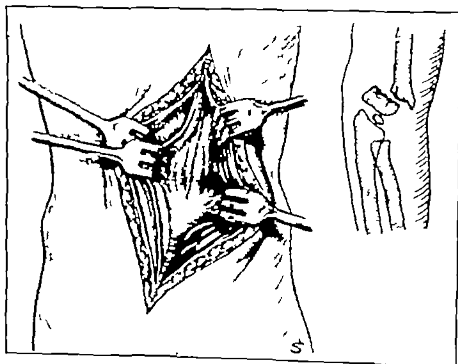


Fig. 855.—Vessels and nerves retracted incision carried through deeper structures into elbow joint and fracture site.

lation does not return following this procedure surgery is indicated. The operation should be carried out as early as possible since the muscle is damaged within a short time. The deep fascia in the antecubital space of the arm and forearm is usually the constricting factor. Division of this fascia is usually sufficient to permit re-establishment of the circulation but not, necessarily a return of function if destruction and degeneration of muscles have already progressed to an irreparable degree.

Technic.—A longitudinal incision is made over the affected artery and the deep fascia is exposed according to the technic illustrated in Figs. 853 854. If, after division of the fascia the circulation returns to the extremity no further surgery is necessary. If the circulation does not return, the artery is exposed and if severed is ligated well above and below the point of severance the intermediate portion is then excised. In the presence of extensive thrombosis, ligation and resection of the traumatized portion of the vessel will usually relieve the reflex spasm from the collateral circulation. If the artery is compressed but not thrombosed, removal of the pressure is indicated. Constriction of the artery from spasm may be relieved by a periarterial stripping. In effect this is a sympathectomy of the artery.

If severed, the median nerve may be sutured provided the patient's condition warrants prolonging the operation otherwise suture of the nerve may be postponed until a later date. Bleeding is controlled and, if necessary a drain is inserted. Only the skin is closed the sutures being loosely tied.

PROCEDURES FOR ISCHEMIC MYOSITIS

Volkmann's contracture of several weeks or a few months duration is best treated by conservative measures. Treatment consists of stretching of the flexor tendons and muscles of the wrist and fingers by special apparatus until the fingers are extended and the wrist is dorsiflexed (Fig. 56). Frequently the finger joints can be extended if the wrist is flexed. If so, a correction splint is applied the hand being fixed to the distal portion of the splint with the fingers in extension, and maintained in this position as the wrist is gradually dorsiflexed. After correction is complete physical therapy is essential. Between exercise periods and particularly at night, the corrected position must be maintained by a splint for a number of months.

The earlier treatment is instituted following contracture the more successful will be the result. In early cases, especially those of only moderate severity improvement may be effected to a degree which obviates the necessity for operation. At best, however normal function is not restored, since there is always some residual muscle deficiency limitation of motion of the joints of the wrist and hand, and trophic changes of the soft tissues.

Operative measures are indicated (1) when the response to conservative treatment is inadequate or (2) if the contracture is of long standing and there are, in addition to muscular contractures, extensive changes in the bones and soft structures. Even in cases of long standing the contracted structures should be stretched as much as possible prior to operation, by the measures described above.

The surgical procedures applicable to Volkmann's paralysis are of two types (1) those wherein the contracted soft tissues are lengthened, such as the Steindler and Bunnell operations (p 1218) and (2) those wherein the bony

Fig. 8 6.—*A* Volkmann's contracture. *B* Range of active motion of wrist and fingers secured by conservative means.

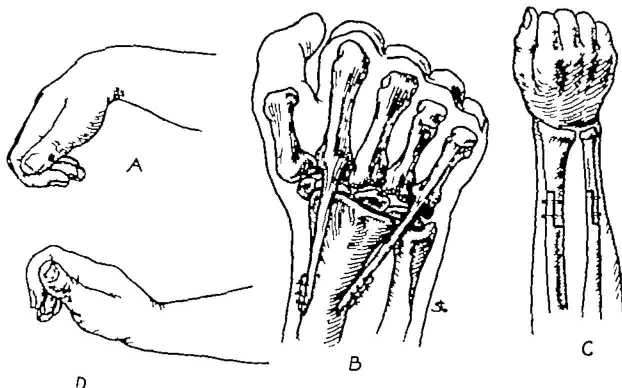


Fig. 887—*A* Volkmann's contracture. *B*, Correction of deformity by excision of carpus and arthrodesis of wrist joint. Extensor carpi ulnaris and extensor carpi radialis longus tendon anchored through radius. *C*, Z plastic resection of both bones of forearm. Shortening of osseous structures permits sufficient relaxation of contracted soft tissues to allow correction of deformity. D Position of wrist after operation for extreme Volkmann's contracture. Even though correction of fingers is impossible in extreme cases of long duration, appearance is improved.

lation does not return following this procedure surgery is indicated. The operation should be carried out as early as possible since the muscle is damaged within a short time. The deep fascia in the antecubital space of the arm and forearm is usually the constricting factor. Division of this fascia is usually sufficient to permit re-establishment of the circulation but not, necessarily, a return of function if destruction and degeneration of muscles have already *progressed to an irreparable degree.*

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The earlier treatment is instituted following contracture the more successful will be the result. In early cases, especially those of only moderate severity improvement may be effected to a degree which obviates the necessity for operation. At best however normal function is not restored, since there is always some residual muscle deficiency limitation of motion of the joints of the wrist and hand and trophic changes of the soft tissues.

Operative measures are indicated (1) when the response to conservative treatment is inadequate or (2) if the contracture is of long standing and there are in addition to muscular contractures, extensive changes in the bones and soft structures. *Even in cases of long standing* the contracted structures should be stretched as much as possible prior to operation, by the measures described above.

The surgical procedures applicable to Volkmann's paralysis are of two types: (1) those wherein the contracted soft tissues are lengthened, such as the Steindler and Bunnell operations (p. 1218) and (2) those wherein the bony

Fig. 856.—*A* Volkmann's contracture. *B* Range of active motion of wrist and fingers secured by conservative means.

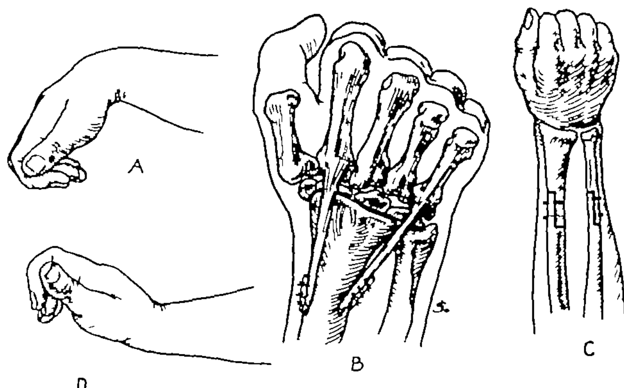


Fig. 857.—*A* Volkmann's contracture. *B*, Correction of deformity by excision of carpus and arthrodesis of wrist joint. Extensor carpi ulnaris and extensor carpi radialis longus tendons anchored through radius. *C*, Z-plastic resection of both bones of forearm. Shortening of osseous structures permits sufficient relaxation of contracted soft tissues to allow correction of deformity. D, Position of wrist after operation for extreme Volkmann's contracture. Even though correction of fingers is impossible in extreme cases of long duration, appearance is improved.

structures are shortened permitting relaxation of the soft tissues, as in White's operation by excision of the carpal bones with or without arthrodesis, or partial resection of both bones of the forearm

Operations on the Soft Tissues

Lengthening of Contracted Tendons

Correction of deformity by attack on the soft tissues alone is reserved for ischemic myositis of mild degree or of recent origin wherein there is little or no distortion of the bones. Even then these procedures are seldom employed unless a fair degree of correction is secured by the conservative measures described above

Technic (Steindler) —*A midline incision is made on the volar aspect of the wrist* The flexor carpi ulnaris and flexor carpi radialis tendons are identified and divided by a Z-plastic incision The tendons of the finger flexors are *then exposed and if excessively contracted are divided in a similar manner* contracture of the flexor pollicis longus tendon usually is more pronounced than that of the other finger flexors. All lengthened tendons are now sutured *under slight tension The sheaths are repaired when possible and the tendons* are amply covered with soft tissue before the skin is closed

Technic (Bunnell) —The length of the flexor fascial compartment of the forearm is exposed Contracted septa are severed between the muscles, thus allowing expansion of the muscle bodies. The nerves and blood vessels are explored and freed throughout their length from strangling cicatricial formations. Muscles hopelessly destroyed by atrophy and fibrous tissue replacement are excised and their tendons are freed to permit extension of the fingers. All shortened tendons are lengthened over a considerable area by longitudinal slits and the ends having been frayed the overlapping portions are reunited by continuous running removable stainless steel wire sutures (*Fig 96*) The sutures are brought out through the skin at each end and fastened by a shot. If the shortening of the bones is necessary Bunnell prefers resection of one *or both rows of carpal bones rather than shortening of* both bones of the forearm

After Treatment.—The wrist and fingers are supported on a cock up splint with the fingers in extension and the wrist in 135 degrees' dorsiflexion. When the wounds are completely healed which is usually after two weeks, extensive physical therapy is instituted The corrected position is maintained between exercise periods.

Bone Shortening Operations

Operations for shortening the bones of the forearm or wrist are usually employed only in severe ischemic myositis of long standing wherein the wrist and fingers are fixed in extreme flexion and the bones are distorted in contour to conform to this abnormal position. A sufficient amount of bone must be resected to permit dorsiflexion of the wrist to 150 degrees. This may be accomplished *by one of two methods resection of the bones of the carpus*, with or without arthrodesis, or partial resection of both bones of the forearm. The latter is less desirable, being more extensive and involving the possibility of nonunion.

Excision of the Carpus Without Arthrodesis

In a *few* cases of neglected ischemic myositis with only moderate deformity the flexor and extensor muscles of the wrist and fingers may still

possess a functional degree of power In this event correction of the deformity is secured by excision of only the proximal row of carpal bones.

Technic.—See p 1049

After Treatment—A cock up splint is applied, maintaining the proper position of the wrist and fingers until healing of the wound is complete Motion is then cultivated by carefully supervised physical therapy as following arthroplasty of the wrist (p 1120)

Excision of the Carpus With Arthrodesis

In an extreme deformity of long standing if the flexor group of muscles is deficient and there is a probability that sufficient power cannot be developed in the extensor muscles, restoration of a practicable degree of function cannot be expected Operation is indicated however if only for improvement in appearance and the salutory effect upon the general outlook of the patient

Technic.—The dorsum of the wrist is incised either transversely or in the midline longitudinally a distance of four inches, the longitudinal approach being preferable. The extensor tendons are separated in the midline by blunt dissection and retracted medially and laterally The deep fascia and dorsal carpal ligaments are divided and with a periosteal elevator or chisel the periosteum and capsule of the wrist are separated, exposing the lower end of the radius and entire carpus. The carpus is then partially or completely removed As a rule, the entire carpus, with the articular surfaces of the bases of the metacarpal bones, must be excised before the bones can be approximated and the wrist maintained at 150 degrees' dorsiflexion The articular surface of the radius is then denuded The tendons of the extensor carpi ulnaris and extensor radialis longus muscles are severed proximally at their musculotendinous junctions. A hole is drilled through the ulna and radius one inch above the joint the tendons are placed through the respective tunnels in the bone and the end of each tendon is stitched to itself, forming a closed loop Small particles of cavernous bone may be taken from the excised carpus and packed in all the crevices and about the approximated osseous surfaces.

After Treatment.—A malleable cock up splint is applied, holding the wrist in 150 degrees dorsiflexion. After two weeks, the stitches are removed and immobilization in the same position is continued by a cast extending from the heads of the metacarpal bones to the upper third of the arm. At the end of eight weeks postoperatively the cast is removed and a leather corset reinforced with steel bars, is fitted to be worn until union is solid Usually this requires approximately six months.

Step-Out or Z-Plastic Resection of Both Bones of the Forearm

Shortening of the osseous structures relaxes the soft tissues sufficiently to permit correction of the deformity of the wrist. This procedure is seldom indicated, however regardless of the degree of the deformity

Technic.—An incision four inches in length is made on the middle and lower thirds of the forearm along the lateral border of the radius. The bone is approached by dissection between the tendons of the abductor pollicis longus and extensor pollicis brevis muscles dorsally and of the flexor carpi radialis longus and brevis muscles on the volar aspect. A second incision of similar length is made along the subcutaneous border of the ulna in its lower third. The radius and ulna are then shortened by a Z-plastic or step-cut procedure

similar in principle to that described for shortening of the femur (p 1454) The wrist is forcibly dorsiflexed before fixation of the fragments.

After Treatment.—A cast is applied from the mid palm to the axilla, holding the wrist in 150 degrees' dorsiflexion and the elbow at 90 degrees, and maintaining the fragments of the radius and ulna in proper alignment. The cast is removed after eight weeks and if union is adequate a cock up splint (p 70) is applied and worn for an additional month being removed daily for physical therapy to the elbow and wrist.

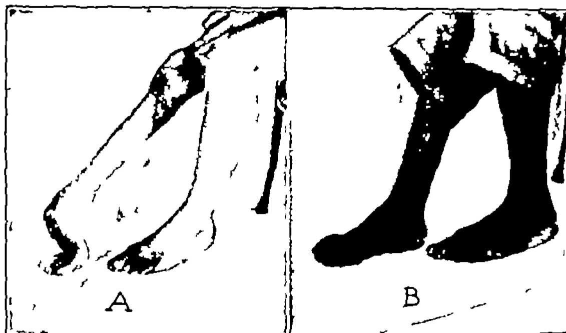


FIG. 853.—*A* Ischemic paralysis of lower extremity from prolonged use of tourniquet following snake bite *B* End result after lengthening of tendo achillis and reconstruction of tarsus.

NERVE COMPLICATIONS ASSOCIATED WITH ISCHEMIC MYOSITIS

Not infrequently there is definite evidence of injury to the ulnar or median nerve or both The nerve may have been severed at the original injury or the lesion may be secondary to scar contracture incident to the ischemic myositis. *The status of fibrosis of the muscles is irreparable.* In a few cases, however improvement of sensory and trophic disturbances may be effected by neurolysis or nerve suture as described in the chapter on Peripheral Nerve Lesions. Operations on the nerves are of course, carried out in addition to measures for correction of the deformity of the hand and wrist described above

ISCHEMIC MYOSITIS OF THE LOWER EXTREMITY

When ischemic myositis involves the lower extremity prophylactic measures similar to those carried out in the arm should be taken to prevent circulatory embarrassment, either from extrinsic constriction by casts or bandages, or from intrinsic pressure on vessels from a fragment of bone or following hemorrhage into closed compartments especially in the popliteal space Because of the location of the division of the popliteal artery into the anterior and posterior tibial arteries and the fact that the former passes forward between the

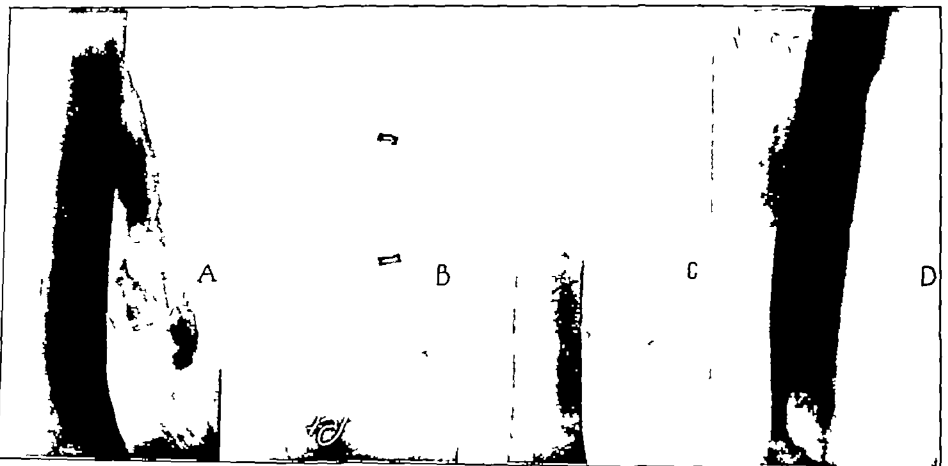


Fig. 889.—*A*, Myositis ossificans, anterior surface of lower third of arm. *B*, After excision. C, Recurrence of metaplastic bone four months later. Excision postponed for one year. *D*, One year later after removal of bony mass.

tibia and fibula and above the interosseous membrane, fractures of the tibia just below the knee joint associated with displacement are most likely to give rise to circulatory disturbances The residual deformity is equinovarus. Operative correction consists of lengthening of the tendo achillis (p 1021) and wedge osteotomy of the tarsus (p 1320)

MYOSITIS OSSIFICANS

Myositis ossificans is a low grade process characterized by the formation of bone within or adjacent to muscle Two types of this affection are observed (1) progressive and (2) circumscribed or traumatic. The progressive type is not amenable to surgery death occurs finally from interference with respiration or intercurrent disorders. In the circumscribed and traumatic forms, bone production usually is limited to a single muscle The treatment



Fig. 860.—Progressive type of myositis ossificans. Multiple areas of metaplastic bone throughout body Not amenable to surgery

is entirely surgical. Removal is indicated because of pain and disability from interference with muscle function. Operation should be delayed until ossification *has ceased and the ossified area has thoroughly matured* as determined by roentgenograms repeated at intervals otherwise recurrence is likely and the recurrent area of ossification may be more extensive than the original process. Generally the process ceases within one year after the growth is first observed.

The muscles more commonly involved are in the order of frequency brachialis anticus, biceps brachii, quadriceps femoris, and adductors of the thigh *Since the brachialis anticus is most often affected* the operation for removal of the mass from this region only will be described

Technic.—An anterolateral incision is made over the prominence of the tumor mass, beginning proximally and extending to the anterior surface of the

elbow joint As the deep structures are incised, the radial nerve at the lower end of the incision is isolated Rarely the muscle must be removed almost entirely If the tumor is in contact with the humerus, the periosteum is incised around its base and the adjacent portion of the humerus resected with an osteotome Complete hemostasis should be secured to prevent a hematoma which may be a prelude to recurrence A roentgenogram is made prior to closure of the wound to determine whether all osseous material has been excised

After Treatment—The arm is immobilized in a right angle elbow splint. Active use is encouraged after four weeks. At intervals of two months, for a period of six months, roentgenograms should be made in order that any recurrence might be detected Roentgen ray therapy following removal may be of some value in preventing a recurrence

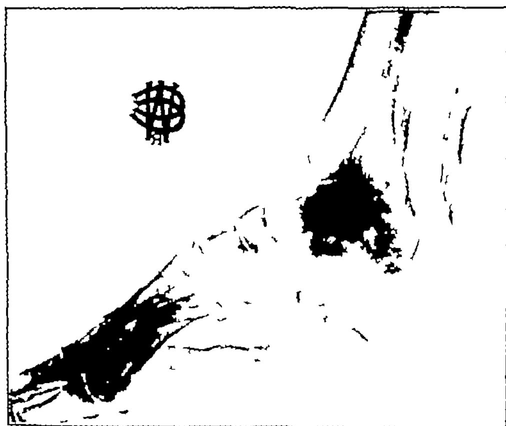


Fig. 141.—Interstitial ossification with bone formation in long plantar ligament and subcutaneous structures in sole of foot. Bone formation in tendo achillis.

INTERSTITIAL OSSIFICATION—OSSIFYING HEMATOMA

Clinically the term interstitial ossification is applied to metaplastic bone formation which is limited to the fascial planes or subcutaneous structures. Pathologically this process does not differ from the type of ossification observed in myositis ossificans.

A hematoma, regardless of its cause or its location whether in a gland, connective tissue muscle, tumor or blood vessel if not absorbed may undergo fibrous tissue organization, or form a center of coagulation or aseptic necrosis which attracts calcium salts. Calcification and ossification of the mass may ensue. Bertwistle is of the opinion that ossification takes place only following

tibia and fibula and above the interosseous membrane, *fractures of the tibia* just below the knee joint associated with displacement are most likely to give rise to circulatory disturbances. The residual deformity is equinovarus. *Operative correction consists of lengthening of the tendo achillis* (p 1021) and wedge osteotomy of the tarsus (p 1320)

MYOSITIS OSSIFICANS

Myositis ossificans is a low grade process characterized by the formation of bone within or adjacent to muscle. Two types of this affection are observed (1) progressive and (2) circumscribed or traumatic. The progressive type is not amenable to surgery death occurs finally from interference with respiration or intercurrent disorders. In the circumscribed and traumatic forms, bone production usually is limited to a single muscle The treatment



Fig. [illegible].—Progressive type of myositis ossificans. Multiple areas of metaplastic bone throughout body Not amenable to surgery

is entirely surgical. Removal is indicated because of pain and disability from interference with muscle function Operation should be delayed until ossification has ceased and the ossified area has thoroughly matured as determined by roentgenograms repeated at intervals otherwise recurrence is likely and the recurrent area of ossification may be more extensive than the original process. Generally the process ceases within one year after the growth is *first observed*

The muscles more commonly involved are, in the order of frequency brachialis anticus, biceps brachii quadriceps femoris, and adductors *of the* thigh. Since the brachialis anticus is most *often affected*, the operation for removal of the mass from this region only will be described

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After Treatment.—The arm is immobilized in a right angle elbow splint. Active use is encouraged after four weeks. At intervals of two months, for a period of six months, roentgenograms should be made in order that any recurrence might be detected. Roentgen ray therapy following removal may be of some value in preventing a recurrence.

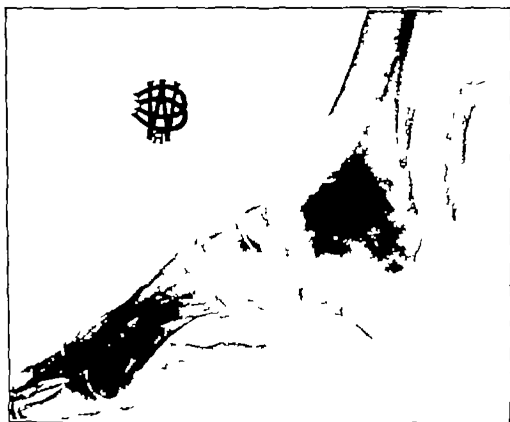


Fig. 861.—Interstitial ossification with bone formation in long plantar ligament and subcutaneous structures in sole of foot. Bone formation in tendo achillis.

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Fig. 560.—Progressive type of myositis ossificans. Multiple areas of metaplastic bone throughout body Not amenable to surgery

is entirely surgical. Removal is indicated because of pain and disability from interference with muscle function. Operation should be delayed until ossification has ceased and the ossified area has thoroughly matured as determined by *roentgenograms repeated at intervals*, otherwise recurrence is likely and the recurrent area of ossification may be more extensive than the original process. Generally the process ceases within one year after the growth is first observed.

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invaded by blood vessels, ossification may take place (Bertwistle) Thus the tendons lose resilience by a natural evolutionary process analogous to those changes in the joints characteristic of hypertrophic arthritis or osteoarthritis and to sclerosis of the arteries and are ruptured by any unusual tension.

Rupture of tendons induced by stress from too powerful muscular action differs from the severance of tendons by sharp cutting materials from without in that, in the former, there is no potential infection, whereas in the latter, there is a distinct possibility of infection, with perhaps serious consequences.

The structures which rupture most often are the supraspinatous tendon quadriceps femoris (rarely the patellar tendon), the tendons and muscles of the biceps brachii the tendo achillis, and the extensor pollicis longus and extensor digitorum communis tendons of the fingers. The technic for repair of these will provide examples for the treatment of all

Fresh Rupture of the Tendo Achillis

In rupture of the tendo achillis the tendon fibers are usually torn into irregular longitudinal strips near the musculotendinous junction or the tendon may be torn near its insertion into the os calcis The former type of rupture is more prevalent in young individuals whereas the latter is more prevalent in persons beyond middle age In either location and in both age groups repair of the severed tendon is difficult.

Technic.—A longitudinal incision approximately four inches in length is made and the ruptured portion of the tendon exposed A pull-out suture of 1 mm rustless steel wire is inserted In a large tendon of this type a modification of the pull-out wire suture employed by Bunnell (p 107) is preferable. The distal wire loop is threaded through the proximal portion of the ruptured tendon beginning at the point of severance passed upward through the severed tendon curved laterally through this tendon and downward through its medial margin and allowed to emerge at the point of severance. Both ends of the suture are then placed on long straight needles and passed downward one or two inches through the medial and lateral aspects of the distal portion of the severed tendo achillis then out through the skin of the sole of the foot. The pull-out wire suture is placed at the apex of the U and passed out through the skin near the center of the calf of the leg (Fig 96) At this point the pull-out suture should be tested to determine whether or not it slips backward and forward freely Traction is maintained on the wires which pass through the heel to relieve the tension on the proposed suture line The frayed ends of the tendons are placed in as nearly anatomic position as possible and the rupture is repaired with multiple small interrupted sutures of silk The wound is then closed in the routine manner The heel and sole of the foot are well padded with white felt, and the pull-out wire sutures are threaded through this padding on the sole of the foot. With the knee in flexion to relieve tension on the suture line a long leg cast is then applied, the wire sutures being allowed to protrude through the cast. Constant traction is maintained on the sutures while the cast is being applied. After the cast has set, the two wires are wound about each other over that portion of the cast which is between the wires.

After Treatment.—The cast is removed at the end of three to four weeks and, under aseptic conditions, the pull-out wire sutures are severed at the skin level and withdrawn. A short leg walking cast is then applied the foot being

invasion of the area of calcification by blood vessels Ossifying hematomas of the extremities develop most commonly following severe trauma with hemorrhage

Either interstitial ossification or ossifying hematoma may produce a mass sufficiently large to interfere with function The treatment is essentially identical to that described above for myositis ossificans.

Calcified masses of a degenerative nature are sometimes seen in the tendo achillis or quadriceps tendon. Usually, these bodies are relatively small and practically confined to the tendon, and do not, therefore, interfere with function. Unduly large masses must be excised.

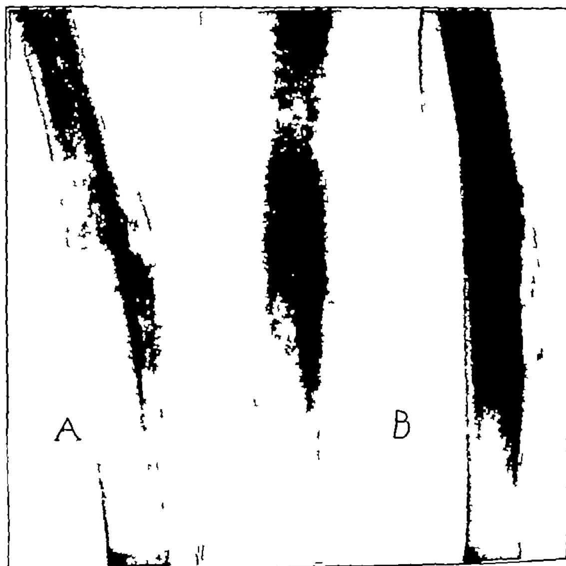


Fig. 862.—*A* Ossifying hematoma following severe trauma to thigh in football game. *B* Mass completely excised, followed by re-formation of new bone.

RUPTURE OF MUSCLES AND TENDONS

Ruptured muscles and tendons frequently must be repaired by open operation. In young individuals, muscles are ruptured *more often* than tendons, whereas in the aged the reverse is true. All structures having a scant blood supply undergo calcification with advancing years and if the calcified area is

invaded by blood vessels, ossification may take place (Bertwistle) Thus the tendons lose resilience by a natural evolutionary process analogous to those changes in the joints characteristic of hypertrophic arthritis or osteoarthritis and to sclerosis of the arteries and are ruptured by any unusual tension.

Rupture of tendons induced by stress from too powerful muscular action differs from the severance of tendons by sharp cutting materials from without in that, in the *former, there is no potential infection, whereas, in the latter,* there is a distinct possibility of infection, with perhaps serious consequences.

The structures which rupture most often are the supraspinatous tendon quadriceps femoris (rarely, the patellar tendon) the tendons and muscles of the biceps brachii the tendo achillis and the extensor pollicis longus and extensor digitorum communis tendons of the fingers The technic for repair of these will provide examples for the treatment of all

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After Treatment.—The cast is removed at the end of three to four weeks and, under aseptic conditions the pull-out wire sutures are severed at the skin level and withdrawn. A short leg walking cast is then applied, the foot being

maintained in slight equinus Using crutches the patient gradually resumes walking with partial weight bearing over a period of approximately two weeks thereafter, walking is permitted without the use of crutches. After four to six weeks, the cast is removed and the patient gradually resumes walking and weight bearing without support.

Neglected Rupture of the Tendo Achillis

In old ruptures, the tendo achillis is in reality elongated, as the space between the severed ends is filled with scar tissue The patient walks to some extent on the heel, as in paralytic calcaneus deformity

Technic.—In the repair of an old rupture of the tendo achillis an incision is made as for fresh ruptures of this tendon (p 1225) The site of the rupture is exposed scar tissue is excised from between the ends of the tendon and the ends are freshened By flexing the knee to 90 degrees, placing the foot in moderate equinus and using a pull-out wire suture for traction (p 107), the ends may in some cases be approximated if so they are sutured with silk according to the technic described above If the ends cannot be approximated, a plastic or fascial repair of the tendon may be required (Fig 851) Strips of fascia lata may be woven into the proximal and distal fragments and the ends of the strips tied or sutured together with small interrupted sutures of silk. Preferably the fascial strips are tied in a single knot and to prevent the knot from slipping small interrupted sutures of silk are inserted.

After Treatment.—This is essentially the same as described for treatment following fresh rupture

Fresh Rupture of the Patellar Tendon

Rupture of the patellar tendon usually takes place at the inferior border of the patella as a consequence the patella is a part of the upper segment and, through contracture of the quadriceps muscle group, may be retracted one or two inches above its normal position Fresh ruptures may be repaired in the manner of rupture of the quadriceps tendon. The technic, therefore, will be described only for neglected ruptures.

Neglected Rupture of the Patellar Tendon

In old separations of the patellar tendon the quadriceps muscle usually must be elongated prior to operation by the use of skeletal traction. A Kirschner wire is passed through the upper portion of the patella from side to side, the utmost care being exercised to prevent the wire from entering the knee joint. Three to five pounds of skeletal traction are applied. From one to four weeks may be required for adequate lengthening of the quadriceps femoris muscle The wire is then removed, or if there is no reaction about the exits through the skin, the wire may be left intact. In the presence of a reaction, a U-shaped incision is preferable to avoid as much as possible both the wire and its exits the traction loop is removed prior to operation, to be reapplied later The wire and adjacent skin are included in the field prepared for operation, but are preferably covered by drapes during the procedure.

Technic.—An anteromedial or U-shaped incision (p 143) is made over the patella and ruptured ligament. The segments are first denuded of all scar tissue and the surfaces freshened A strip of fascia lata one inch wide and four inches long is taken from the thigh above, inserted through a hole drilled

in the patella, woven in a purse string manner through the patellar ligament below The ends of the fascial strip are sutured together with interrupted silk In addition multiple small mattress sutures of silk may be used to unite the ends of the ligamentous segments

After Treatment.—(See p 1229)

When preliminary traction is not feasible, the operation is identical to that for repair of neglected rupture of the quadriceps femoris tendon The tendon transplant or fascia lata is used to fill the gap, being inserted through a hole drilled in the patella and through the distal portion of the patellar ligament as a purse string suture

Gallie and LeMesurier reconstruct the ligamentum patellae by passing two stout strips of tendo achillis through drill holes in the patella from above downward to the tibia

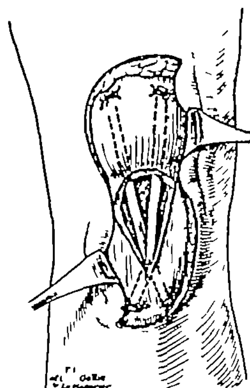


Fig 863—Operation of Gallie and LeMesurier for neglected rupture of patellar tendon. Continuity restored by segments of tendo achillis. (Redrawn from Gallie, W E, and LeMesurier A. B. J Bone & Joint Surg. 9: 47 1927)

Technic (Gallie and LeMesurier)—Through a straight or S-shaped incision, the ligamentum patellae and the tuberosity and upper portion of the shaft of the tibia are exposed After removal of the scar tissue from between the remains of the ligamentum patellae the ligament is split in the midline from the patella to the tuberosity Two vertical or longitudinal holes are next made through the patella from above downward by means of a three-sixteenths inch drill. Then, with a five-sixteenths inch drill a hole is made into the tibia at the tubercle Two additional holes, three-sixteenths inch in diameter are next drilled through the cortex of the tibia below the tuberosity, being so inclined as to communicate with the larger hole above A segment of the tendo achillis, consisting of half its thickness and seven inches of its length, is removed The plantaris tendon is excised for use as a suture. The segment of the tendo achillis is split longitudinally into two equal parts, drawn through

the holes in the patella and tibia, and, with the patella pulled distally is sutured in place under tension. The ends of the ruptured ligamentum patellæ are fastened together with a suture made from the plantaris tendon.

After Treatment.—(See p 1229)

Fresh Rupture of the Tendon of the Quadriceps Femoris Muscle

The quadriceps tendon usually is ruptured transversely at a point just above the patella Repair should be undertaken within twenty four hours, if possible, although suture of the segments within thirty days after injury may be followed by primary union.

Technic.—Beginning three to four inches above the patella, the skin is incised parallel with the inner border of the quadriceps tendon to the inferior *margin of the patella. Dissection is carried beneath the deep fascia,* exposing the separated ends of the quadriceps tendon and the patella. A space of one

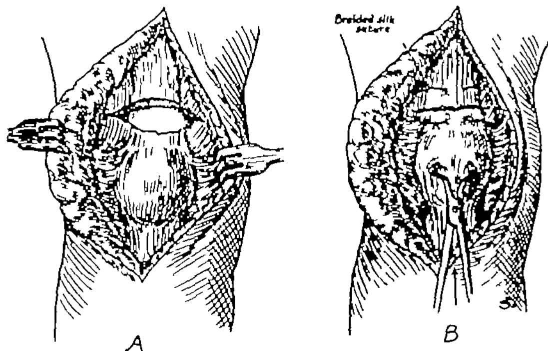


Fig. 884.—*A* Operation for fresh rupture of quadiceps tendon. *B* Rupture repaired with mattress sutures of braided silk.

inch or more usually is observed, the suprapatellar pouch of the knee joint being apparent in the interval Two mattress sutures of fascia lata may be placed through the ends of the tendon these generally being one inch apart, and the ends approximated by traction on the proximal fragment with an ordinary towel clip The fascial sutures are tied and the knot secured by small interrupted sutures of silk. If the ends cannot be easily approximated, or if the operator does not wish to use fascia lata the retraction of the quadriceps tendon may be counteracted by means of a wire pull-out suture similar to the one described for severance of the tendo achillis. The pull-out wire emerges from the skin on the anterior surface of the thigh near the junction of the middle and lower thirds. The two wire sutures encircling the quadriceps tendon are allowed to emerge from each side of the patellar tendon. By traction on the wires, the gap in the quadriceps tendon is closed and the ends of the tendon are united with multiple interrupted silk sutures.

After Treatment.—A posterior gutter splint having a foot piece is applied to hold the knee in complete extension If a pull-out wire suture has been used a strong rubber band, made from inner tubes or a Spanish windlass, is attached to the foot piece of the splint to maintain traction on the wire suture If the wire is fastened over buttons, as is employed for the hand, the power of the quadriceps muscle will cause a slough of the skin beneath the buttons Five to ten pounds of traction on the end of the splint are usually necessary to prevent the splint from pulling upward on the leg The pull-out wire and splint are removed at the end of three weeks and active and passive movements are cautiously instituted Walking is also permitted with support by a control dial knee brace (p 38) so arranged that flexion may be increased commensurately with healing and improvement in tensile strength of the sutured tendon After eight weeks full extension of the knee and flexion to 130 degrees should be possible At three months postoperatively flexion should be increased to 90 degrees, and within six months to one year the maximum degree of flexion should be restored

Rupture of the quadriceps tendon is usually observed in individuals beyond middle age For this reason complete flexion of the knee is seldom obtained following repair of the rupture As 90 degrees of flexion of the knee is sufficient for ordinary activity however the advisability of special efforts to increase the motion beyond this point is questionable The repair of the tendon is most important at any age but especially so in the elderly, as the instability of the knee may lead to frequent falls and consequent injury of other parts, particularly the hip

Neglected Rupture of the Tendon of the Quadriceps Femoris Muscle

After the passage of months or years, rupture of the quadriceps tendon presents a difficult problem. A space of one to two or more inches exists between the ends of the tendon and must be repaired by a plastic operation or a transplant of tendon or fascia

Technic.—The tendon is approached through the incision described for fresh ruptures, and the ends are completely denuded and freshened. A transplant of the peroneus longus tendon or of fascia lata is removed from the opposite extremity If a segment of the peroneus longus tendon is chosen an incision is begun just posterior to the external malleolus and extended proximally six inches. The fascia and sheath are incised The peroneus longus tendon, which is the more superficial, is withdrawn a segment approximately six inches in length is resected, and the proximal end is sutured to the peroneus brevis tendon.

With a scalpel, one fourth inch longitudinal incisions are made through one-half the thickness of each fragment of the quadriceps tendon, one inch from the ruptured ends, and the tendon is raised between these incisions to form at least three tunnels. A small hemostat is inserted through the apertures and the transplant is interwoven through both fragments of the tendon. The ends of the transplant are then drawn together in purse string fashion pulled tightly and sutured together and to each end of the ruptured tendon with interrupted silk sutures. It may be desirable to relieve the tension on the suture line by inserting a wire pull-out suture (p 107)

Fascia lata, if preferred, may be utilized in a similar manner

After Treatment.—See above

The results are less satisfactory than those of repair of fresh ruptures, although stability is improved and a practical range of motion in the knee is regained. Full forcible extension is rarely restored.

SUPRASPINATUS SYNDROME

(Lesions of the Musculotendinous Cuff of the Shoulder)

Since the first edition of this book was written many excellent articles have appeared in the literature dealing with lesions of the musculotendinous cuff of the shoulder including those of Codman Bosworth McLaughlin, Laurence Jones Outland and Shepherd and Inman Saunders, Abbott, and

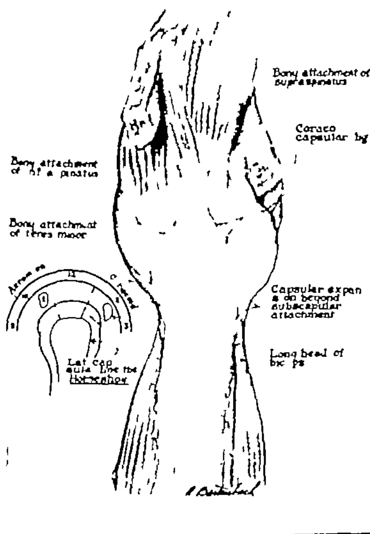


Fig 863.—Identification of various components of musculotendinous cuff, facilitated by a study of 'horseshoe' and 'clock' (Laurence Jones) Viewing right shoulder from lateral aspect with joint in neutral rotation, outline of greater tuberosity, called 'horseshoe,' receives attachment of supraspinatus tendon (horizontal limb) subscapularis (anterior vertical limb) and infraspinatus-teres minor muscle (posterior vertical limb) In hiatus between supraspinatus and subscapularis, the coracocapsular or coracohumeral ligament is visualized. From 'horseshoe,' tendons fan out proximally as represented by "clock" diagram. Supraspinatus is between eleven and one o clock, coracohumeral ligament at one o clock and subscapularis tendon between one and three o clock. Upper edge of posterior capsular component is at eleven o'clock and extends *distally toward nine o clock.* (*From Jones, Laurence:* Surg., Gynec. & Obst. 75: 433, 1942.)

Armstrong Most of this work has been stimulated by Codman's classic, "The Shoulder" Before operating for this condition the surgeon should review the anatomy of the shoulder (Figs 865-867) and the works of a few of these authors In the following section, we have drawn heavily from the above sources, departing from a concise format more details ancillary to treatment will minimize supplementary reading

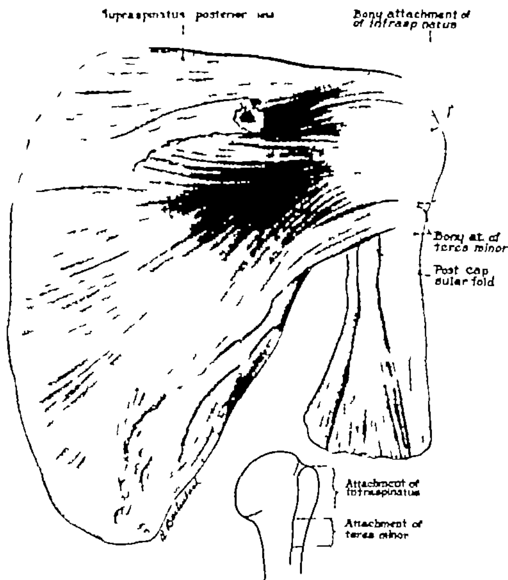


Fig 868.—Posterior view of short shoulder muscles, showing insertion of supraspinatus tendon into top of "horseshoe," and infraspinatus teres minor conjoined tendon into vertical posterior limb of "horseshoe." (From Jones, Laurence Surg Gynec. & Obst. 75: 433 1942.)

The proximity of the supraspinatus tendon to the shoulder joint and its synovial lining its relationship to the subacromial bursa the *coraco-acromial* ligament, and the acromion process creates considerable confusion and difficulty in differentiating many commonly associated clinical entities, such as

complete or incomplete tendon rents or ruptures, calcified or ossified deposits, tendinitis, subacromial bursitis periarthritis, or monarticular lesions of the joint. In fact, many monarticular lesions of the shoulder associated with pain over the supraspinatus attachment, limitation of motion and muscle spasm may present a situation wherein it is impossible to differentiate primary and secondary lesions other than by direct visualization.

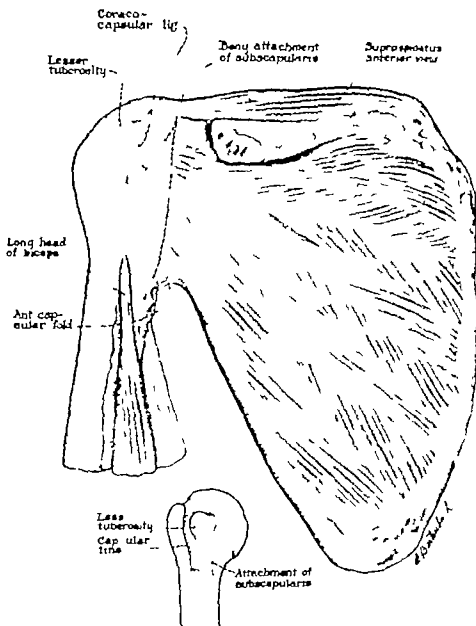


Fig. 867.—Anterior view of shoulder joint and subscapularis muscle and tendon. Subscapularis attaches to lesser tuberosity and to anterior and posterior margins of bicipital groove, forming anterior vertical limb of horseshoe. (From Jones, Laurence: Surg., Gynec. & Obst. 75: 433, 1942.)

Bosworth has grouped a large number of lesions which directly or indirectly involve the supraspinatus tendon under an all-encompassing term, the supraspinatus syndrome. Since a distinction between many of these entities is practically impossible by clinical examination, this term is perhaps

as good as any other Also since the treatment of the vast majority of these lesions follows essentially a single pattern we shall use this term in the subsequent discussion For the purposes of treatment all are grouped together, with the exception of complete avulsions or ruptures of the tendons of the capsular muscles attended by loss of motor function and the so-called "arm drop" sign The latter are discussed separately below

In general patients with a supraspinatus syndrome present themselves with more or less the same signs and symptoms namely, pain muscle spasm, limited motion (both voluntary and involuntary) muscle atrophy, and tenderness over the insertions of the rotator muscles usually the supraspinatus facet of the greater tuberosity These symptoms vary in degree depending somewhat upon the nature and duration of the lesion A relatively low grade lesion which has persisted over a period of months and has been attended only by a series of minor symptoms may suddenly become acute Bosworth for example found calcification in one or both shoulders of 2.7 per cent of 6 061 supposedly normal persons who had a fluoroscopic examination of both shoulders From this it is obvious that this condition may be asymptomatic. Other lesions follow a long chronic course accompanied by symptoms of perhaps moderate severity ultimately producing ankylosis of the shoulder i.e., the so-called "frozen shoulder"

As pointed out by Jones complications and sequelae frequently mask a diagnosis of rupture of the supraspinatus tendon. This to a degree accounts for the disproportion in clinical diagnoses of rupture of the supraspinatus tendon and the postmortem findings of rupture in between 15 and 20 per cent. Undoubtedly, the reported clinical figures on complete rupture of the supraspinatus tendon do not reflect the true incidence

The diagnosis of minor tears presents an even more difficult problem. If the continuity of the capsular cuff is not interrupted to a material degree, muscular functions continue On the contrary there is an inevitable group of symptoms from so-called bursitis. Bosworth and McLaughlin aptly apply the term "internal derangement of the subacromial joint" as the tendon defect is forced beneath the acromion or the coraco-acromial ligament actual locking incidents may occur Although other signs and symptoms may be present incident to the absence of a specific muscular defect they compare the tentative diagnosis of incomplete rupture of the supraspinatus tendon with the situation in the knee joint wherein the term "internal derangement" is employed to cover a multitude of possible diagnoses, the exact nature of the lesion being distinguishable only upon exploration of the joint in question. Whether the minute rupture is superficial, deep or in the substance of the tendon the mechanical irritation from pinching of the area between the humerus and the acromion or the coraco-acromial ligament produces signs and symptoms which may warrant surgical intervention.

It is generally recognized that the majority of minute or complete tears of the supraspinatus tendon are superimposed upon a degenerative lesion, usually in persons beyond middle age Jones emphasizes the fact that, with advancing years the tendon is subjected to degenerative changes as are other fibrous tissues the changes are likely to be exaggerated however because of the forces which pull in all directions at the focal point of attachment of the tendon to the greater tuberosity At this point of weakness minor trauma will produce a rent in the tendon The four component forces continue to pull on this small rent, thus preventing healing Nature's attempts to repair

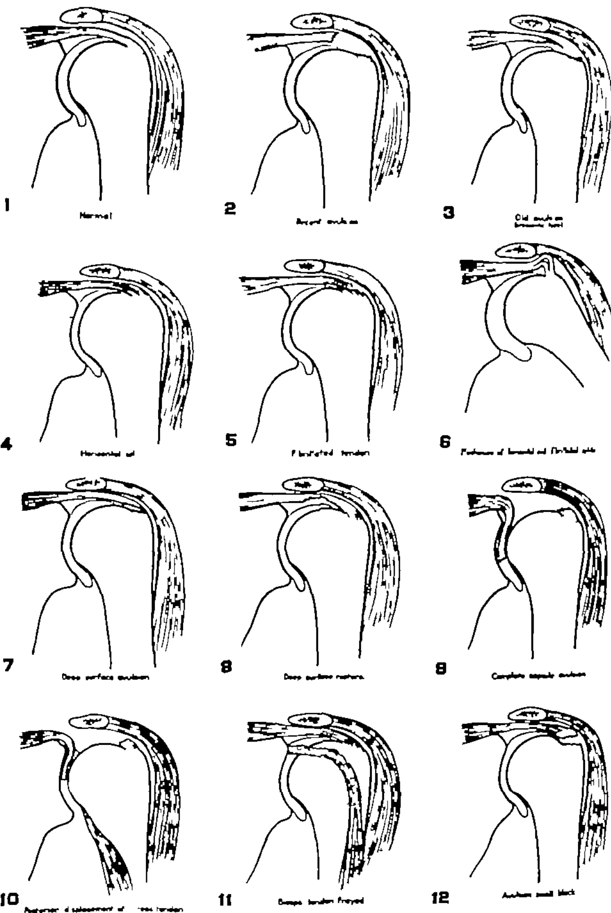


Fig 868.—Bosworth classification of shoulder lesions. (From Bosworth, D M.: J. A. M. A. 117 422, 1941.)

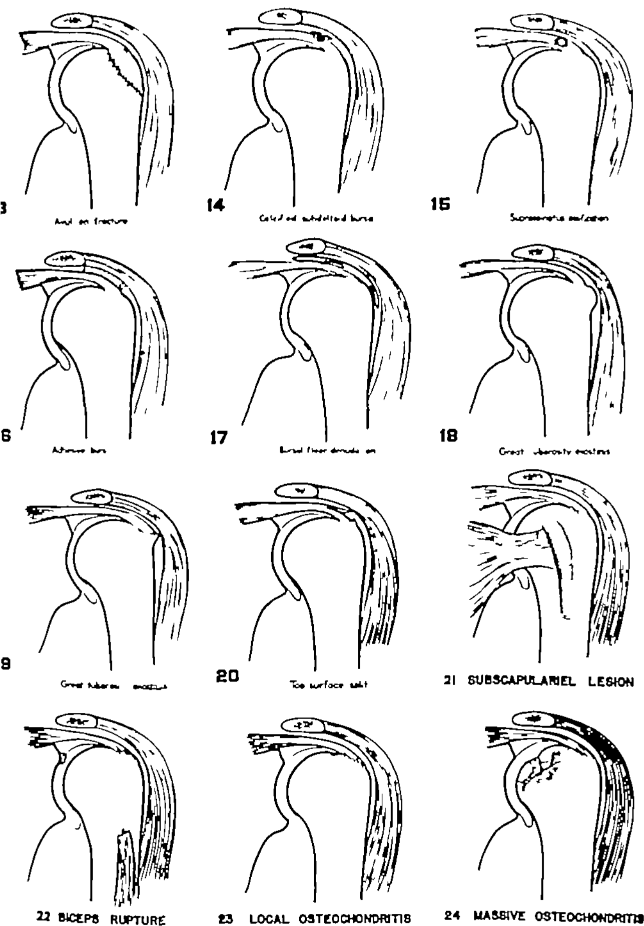


Fig 809.—Same as Fig 808, continued.

this defect merely lead to an excess of granulation tissue at the site of the tear, frequently with the deposition of calcium another evidence of frustrated efforts to heal the lesion. A local lesion in turn, produces an adjacent chronic inflammatory reaction of the subacromial bursa, or a periarthritis.

McLaughlin points out that frictional trauma is inflicted upon the supraspinatus tendon as it passes backward and forward between the head of the humerus and the acromion process or the coracoclavicular ligament. As minute ruptures are replaced by scar tissue, the tendon loses its normal elasticity is thinned out, and no longer serves as an efficient shock absorber between the head of the humerus and the acromion, thus, friction between the acromion and the humerus is increased on motion of the shoulder The bursa then becomes the seat of a chronic inflammatory process with proliferative folds which pass with difficulty beneath the acromion and the falciform edge of the coraco-acromial ligament. This accounts for some of the so-called snapping shoulders. Since these changes are more or less proportionate to the age of the patient and the accumulated wear and tear on the shoulder the majority of lesions of the supraspinatus tendon develops in the middle decades of life.

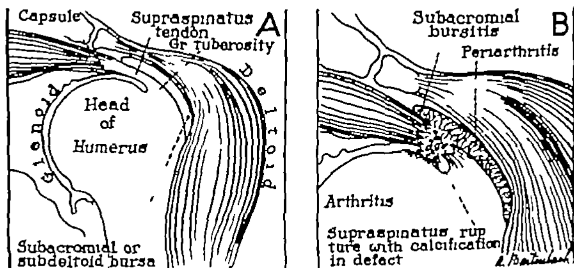


Fig. 870.—A Cross section through shoulder joint shows anatomic inter-relation between head of humerus, supraspinatus muscle and tendon, capsule, subacromial bursa, and deltoid muscle. Note that tendons of capsular muscles fuse with capsule bef re final bony insertion to form a conjoined tendon, i.e., the musculotendinous cuff. B Many lesions follow and complicate rupture of the tendon, thus, the diagnosis, "supraspinatus yndrome. Abnormal calcification, subacromial bursitis, periarthritis, arthritis, and bicipital tendinitis may be associated with supraspinatus rupture. (From Jones, L.: Arch. Surg. 49: 390, 1944)

Laurence Jones calls attention to the occasional rupture of the long head of the biceps tendon in association with large-scale rents of the capsular muscle. He explains this by the fact that the rent allows the weight of the arm to sag, putting the long head of the biceps on stretch and inciting a tendinitis. With the passage of time the tendon is flattened out, frayed and eventually ruptures.

Conservative Treatment of *Supraspinatus Syndrome*

All of these lesions are treated in much the same manner with a few exceptions. Treatment is not directed toward a specific lesion rather palliative measures are carried out for the signs and symptoms particularly pain limitation of motion and muscle spasm and atrophy Physical therapy in the form

of heat, massage, properly directed exercises, and in some cases, temporary immobilization between exercise periods until the more acute episode has subsided, are frequently adequate. As a rule, conservative therapy should be given an adequate trial before any radical measures are undertaken.

In some of the more resistant lesions attended by adhesions of the subacromial bursa and the periarticular structures, the routine physical therapy measures must be supplemented by manipulation under anesthesia in order to restore motion. If bone atrophy is rather extensive, this procedure (p. 1046) must be carried out with care to prevent fracture.

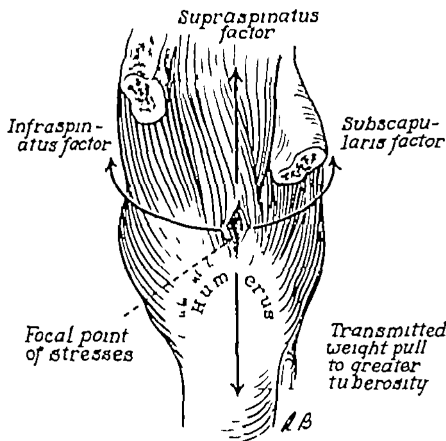


Fig. 871.—Two horizontal and two vertical components of force combine to prevent healing of tendinous lesions. (From Jones L. Arch Surg 49: 390, 1944.)

Abnormal calcifications in the short rotator muscles present a clinical lesion for which additional therapy is available beyond the routine measures described above, namely aspiration and needling of the calcified mass. In most cases these calcified areas appear in the lateral portion of the supraspinatus tendon two view roentgenograms should be made to verify this fact. Large calcified masses may develop in the anterior portion however as well as the superior and posterosuperior portions of the capsular cuff. In the presence of involuntary and voluntary muscle spasm it may be difficult to make a curved cassette lateral view of the shoulder. It is essential that the exact location of the calcified mass be ascertained by both clinical and roentgenographic examination before treatment is instituted. Usually clinical examination is quite accurate. As a rule by proceeding cautiously with mild palpation a small, definite area of tenderness may be elicited. If the musculature is relatively thin, even the outlines of the calcified area may be palpated. The patient frequently indicates localized painful areas over the pos

terior aspect of the shoulder the bicipital groove the acromioclavicular joint and along the insertion and origin of the deltoid muscle. These areas, however, are usually not tender to palpation The most exquisitely tender area should be marked on the skin before operation.

Roentgenograms are of value not only in locating the calcification, but also to a degree in an estimation of the prognosis the fluffier more irregular, less dense lesions (frequently, a relatively acute lesion of short duration) often respond in a dramatic and rapid fashion to aspiration and needling the more dense, round circumscribed lesions (ordinarily associated with a relatively long and chronic group of symptoms) are less responsive.

Aspiration and Needling of Abnormal Calcifications.—The patient is placed on the table in a semisupine position with a sandbag under the affected shoulder, the arm lying against the chest or abdomen. If the shoulder is allowed to extend slightly beyond the table the tuberosity is more prominent. The most equisitely tender point is marked on the skin and the patient is instructed not to change position. After sterile preparation and draping of the shoulder a relatively small needle is directed downward into the calcified mass. With experience one develops a sense of feel as the needle enters the calcified mass a sensation of grating and crepitation is transmitted to the operator's hand Barbotage with a syringe will verify the fact that the needle is in the calcified area. Small white, calcified particles float into the fluid in the syringe as a white cloud soon settling in the most dependent portion of the syringe. In some cases the calcification is under so much pressure that the particles extrude backward into the syringe as soon as the needle protrudes through the encapsulating fibrous tissue A needle of slightly larger caliber and of the same length is then directed parallel with the first needle into the calcified mass and the smaller needle is removed By barbotage as much or more of the calcified mass may be removed as by the use of two needles and a continuous irrigation process. The latter tends to cut a constant channel through the calcified area since the fluid rapidly returns clear through the second needle one is misled into believing that the calcified area is eradicated. Barbotage in a closed system more effectively stirs up the calcified particles. By slightly increasing and decreasing the depth of the needle removal of the calcium is expedited. If a 1 per cent solution of Novocain is used in the syringe for this barbotage process, the acute pain experienced during the first few seconds of this procedure disappears. Once anesthesia is complete saline may be substituted for the Novocain.

After the fluid in the syringe clears and no further calcium particles can be removed the entire area should be thoroughly punctured with a large caliber needle, i.e. pin-cushioned Theoretically, this creates multiple small openings into the bursal sac thereby providing easier ingress for adjacent capillary tufts, and perhaps eventually complete eradication of the abnormal calcification. These openings also provide the particles with avenues of escape into the adjacent subacromial bursa, where they can be absorbed.

Immediately after this procedure patients with more acute lesions are able to move their shoulders to a full range of motion with little or no pain. Those with more chronic lesions attended by adhesions have proportionately less motion, and may still have some residual pain in the extremes of motion, particularly external rotation, internal rotation and abduction.

After Treatment.—Before the anesthesia subsides, the patient is instructed in 'hanger exercises. These are to be performed gently every two hours during the day The shoulder is encased in a warm wet pack during the

night During the first two or three days rigorous physical therapeutic measures should supplement the exercises Once the bursal sac has been adequately ruptured (we have never succeeded in removing all of the calcium by this measure) we believe that constant motion of the shoulder tends to extrude the calcified particles from the relatively fibrotic and avascular tendon into a more vascular field where they can be either encompassed or absorbed

Surgical Treatment of Supraspinatus Syndrome

Thus far, all of the lesions which constitute the supraspinatus syndrome have been treated by a relatively conservative regime In most cases, radical procedures are not justified until the elapse of eight to sixteen weeks If improvement does not progress and pain muscle spasm and limitation of motion still preclude a reasonable degree of function of the shoulder joint exploration of the shoulder is warranted although the exact nature of the lesion may not be well understood As pointed out by both Bosworth and McLaughlin the operation is comparable to exploration of the knee joint for internal derangement i e., an exploration to determine the exact pathologic process, combined with appropriate corrective surgery

Exploration for Supraspinatus Syndrome—The McLaughlin transacromial approach (Fig 134) begins with an incision on the posterior aspect of the acromion which parallels the acromioclavicular joint and extends downward and forward over the anterior aspect of the shoulder joint for a distance of 3 to 5 cm. The anterior portion of this incision is deepened through the deltoid fibers to expose the subacromial bursa and the coraco-acromial ligament The latter is incised and retracted In splitting the deltoid muscle one should be cognizant that the axillary nerve branches may be damaged if dissection is carried downward from the acromion for more than 4 centimeters Detachment of some of the fibers of the deltoid from the acromion provides an adequate exposure for removal of calcified deposits or excision of the bursa To obtain a fairly complete view of the fields, the shoulder must be rotated through all the extremes of motion in this manner one may determine the status of the musculotendinous cuff

The exposure at this point is totally inadequate for surgery on the superior aspect of the musculotendinous cuff An excellent exposure both for repair of the musculotendinous cuff and for procedures adjacent to the tuberosities, may be provided by division of the acromion with an osteotome or a hand saw parallel to the acromioclavicular joint in an anteroposterior direction The lateral fragment of the acromion with the deltoid is then retracted laterally and downward. For complete exposure of the interior of the joint, a longitudinal incision is made from the greater tuberosity toward the coracoid process in the axis of the fibers. This incision usually follows the coracocapsular ligament i e the junction of the subscapularis with the supraspinatus tendon Through this exposure in the musculotendinous cuff the interior of the shoulder joint can be adequately explored A longitudinal incision through the capsule at this point is not subjected to tension and heals readily after side-to-side sutures.

Subsequent surgery depends upon the pathologic process and may consist of any or all of the following procedures

(1) Excision of adhesions and manipulation for frozen shoulders
(2) Excision of abnormal calcifications
(3) Repair of incomplete tears of the musculotendinous cuff
(4) Exostectomy

(5) Acromioplasty

(6) Repair of complete tears (McLaughlin, p 1244 Laurence Jones, p. 1247)

Excision of Adhesions and Manipulation for Frozen Shoulder —This procedure actually begins with the transacromial exposure. On division of the *acromion process and retraction of the deltoid laterally*, the dense adhesions in the subacromial bursa are encountered and detached from these structures. By sharp dissection the scar tissue of the subacromial bursa is then completely excised The division of the coraco-acromial ligament and removal of adhesions in this region usually complete the dissection on the superior and anterior aspects of the shoulder

Articular or periarticular adhesions frequently cause limitation of motion, particularly in external rotation and abduction For this reason, the shoulder is manually forced, if possible through a normal range of motion. Considerable caution must be exercised when forcing the shoulder into abduction and external rotation because of the danger of producing an anterior or subglenoid subluxation or a fracture of the surgical neck of the humerus. The contracted pectoralis major latissimus dorsi and subscapularis muscles serve as a fulcrum in the production of these complications. The 'crack'' associated with the release of ''adhesions'' may actually be a rupture of the subscapularis tendon The technic of manipulation is described on p 1046

Excision of Abnormal Calcification.—As a rule calcified areas are encased *in a relatively tough, fibrous tissue envelope the mass being raised* above the surface of the tendon is a mechanical impediment to motion of the supraspinatus tendon beneath the acromion. The raised area is incised in line with the axis of the fibers of the capsule The contents of the cavity are curetted out and the cavity thoroughly lavaged The defect may be repaired by excision of the adjacent walls of the cavity to healthy tissue and partial or complete closure by side-to-side sutures. More extensive defects may be repaired by the method described below for a deep transverse rent of the *supraspinatus* tendon (Fig 872)

Repair of Incomplete Rents in the Musculotendinous Cuff —Both McLaughlin and Bosworth have pointed out that the most common incomplete rent cannot be visualized by a mere view of the subacromial bursal floor that the superficial portion of the tendon may appear relatively normal while the deep surface presents a rather massive transverse tear and a mobile flap which is folded on itself.

Technic (McLaughlin) —An incision along the course of the coracohumeral or coracocapsular ligament provides adequate exposure of the deep tears. The supraspinatus tendon is detached by a transverse incision along the greater tuberosity proportionate to the length of the deep rent. Another incision is then made parallel to the first and essentially in line with the juncture of the infraspinatus and supraspinatus tendons. The supraspinatus flap is next mobilized, and the pathologic tissue on the *lateral end of the tendon* flap is excised transversely With a chisel a trench of cancellous bone is created at the approximate level of the anatomic neck and the remainder of the supraspinatus flap is buried in this trench The flap is fixed by sutures passed through the tendon and through holes drilled in the humerus. The repair is completed by side-to-side sutures of the supraspinatus to the adjacent subscapularis tendon and the infraspinatus tendon

The smaller lesions on the superficial surface, or those within the substance of the tendons may be excised by elliptical incision in line with the axis of the fibers. The defect is closed by side-to-side sutures.

Exostectomy.—Bosworth reports three cases wherein excision of an exostosis from the greater tuberosity was necessary because of the mechanical impediment and because of symptoms produced by impingement of this structure on the acromion. In two of the cases the exostoses were rounded and excision was carried out in conjunction with repair of a tendon laceration. In the other the exostosis was excised in the following manner: since the bursa was intact over the exostosis, the periosteum was divided one inch below the lesion and dissected proximally well onto the tendon, the bursal floor being left intact. After excision of the exostosis the periosteum and bursal floor were replaced.

Acromioplasty.—Following the full transacromial approach (p. 159), the acromion process having been severed, the lateral fragment is removed from its soft tissue attachment, the medial fragment beveled and reshaped, and the deltoid muscle reattached to the remnant.

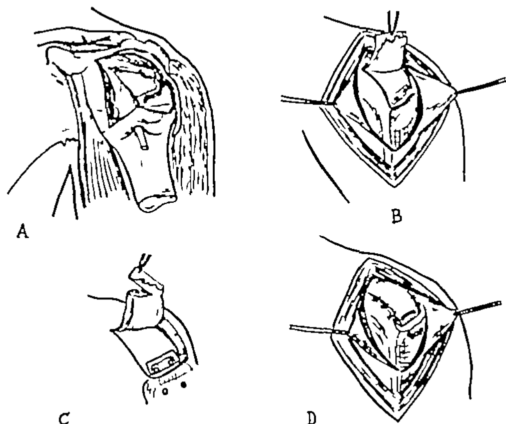


Fig. 872.—Method of repair of incomplete tears of deep surface of musculotendinous cuff. *A*, Exposure of tear through incision in line with fibers of coracohumeral ligament. *B*, Supraspinatus flap mobilized. *C*, Pathologic portion of tendon excised. *D*, Flap fixed by sutures passed through tendon and holes drilled in humerus. Side-to-side sutures through adjacent subscapularis tendon and infraspinatus tendon complete repair. (From McLaughlin, H. L.: Regional Orthopedic Surgery and Fundamental Orthopedic Problems, Ann Arbor, 1940, J. W. Edwards.)

We can think of no contraindication to acromioplasty unless the patient is a young individual with athletic ambitions, particularly a football player. As pointed out by Smith-Petersen, McLaughlin, and others, removal of the acromion process apparently has no harmful effect. Removal of the lateral portion of the acromion is followed by less friction to lesions of the musculotendinous cuff on abduction movements of the shoulder. If a fairly extensive acromioplasty is performed, only a very thin medial fragment being allowed to remain, the more lateral lesions of the cuff do not impinge until the shoulder is abducted well past 90 degrees. Further, the reduction of the normal fric-

tional element facilitates early rehabilitation and subsequent pain and wear and tear are less severe The power of the deltoid muscle is not impaired by this procedure, since the muscle is reattached at a level sufficiently proximal to take up the slack from the loss of its former bony attachment.

After Treatment.—The shoulder is immobilized on an abduction humerus splint at 135 degrees' abduction Immobilization is continued until the wound has healed Ordinarily, physical therapy and graduated exercises may be instituted at the end of two weeks, or, in some cases, earlier For lesions with defects requiring repair of tendons, particularly following a rent in the deep layer of the supraspinatus tendon, immobilization must be continued for a proportionately longer period

COMPLETE RUPTURE OF SUPRASPINATUS TENDON

There is considerable difference of opinion as to the criteria for exact diagnosis and the indications for operation on a patient with rupture of the shoulder cuff Complete or almost complete rupture of the supraspinatus tendon is not in itself an indication for operative repair

Of 60 cases of proved rupture of the shoulder cuff reported by McLaughlin the *majority were in laborers over forty years of age.* Eleven of his patients were under forty and nineteen were women. The rupture was not always induced by trauma, though trauma sufficient to rupture a previously weakened and degenerated tendon was usually reported According to his observations the rupture is accompanied by sudden sharp pain in the shoulder the pain then subsides, but recurs after a few hours. The pain increases for a few days, then passes its peak of intensity and again gradually subsides. McLaughlin also states that, since the shoulder cannot be examined well during the acute stage, a definite diagnosis cannot be made. This being true, he does not advocate surgery during the acute stage, rather he feels that surgery is unnecessary at this time as repair may be accomplished as readily at a later date His results have been equally as good from late as from early operation

Since the rupture usually takes place through a degenerated tendon, repair of a fresh tear is carried out in a manner similar to that of an older rupture. After the acutely painful stage has subsided functional tests are made. If the patient cannot maintain abduction of the shoulder against two finger resistance ' a tear of one inch or more is generally present. This test should be made with the shoulder in all phases of rotation and will be positive only when the torn portion of the cuff is in the position creating functional demand. ' As a rule ruptures of one or more tendons result in an inability to maintain abduction Inability to initiate or maintain abduction generally indicates a *massive avulsion of the cuff*

If the patient's pain and other symptoms are sufficiently severe in his own mind, operation is justified Otherwise surgery should be postponed, as the disability may improve spontaneously

McLaughlin classifies the complete rupture of the musculotendinous cuff of the shoulder as

(1) Pure transverse ruptures
(2) Pure *vertical rents or longitudinal* splits in line with the axis of the cuff fibers
(3) Tears with retraction
(4) Massive avulsions of the cuff

Transverse Ruptures

According to McLaughlin, pure transverse rents with minimal retraction are relatively rare Since the sides of the torn portion maintain capsular continuity and minimal retraction a direct end to-end suture, by the technic described below by Wilson is suitable

Technic (Philip Wilson) —To determine the nature of the lesion an incision two inches long is made downward from the acromioclavicular joint splitting the fibers of the deltoid muscle By limiting the incision to this length the anterior portion of the circumflex nerve is not disturbed. The incision is then continued posteriorly from the acromioclavicular joint over the top of the shoulder the articulation is divided with a knife and the base of the acromion cut through with an osteotome or Gigli saw The outer flap which includes the tip of the arch of the shoulder girdle and the attached deltoid is retracted outward As this provides a wide exposure of the capsule and tendons overlying the head of the humerus, the full extent of the rupture can be determined

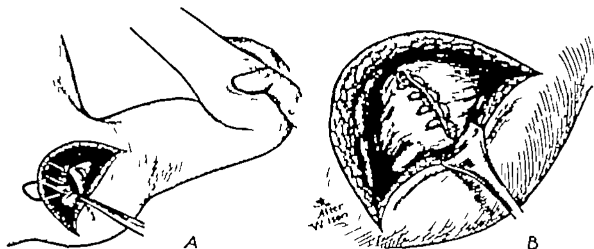


Fig. 473.—Pure transverse rents in supraspinatus tendon with minimal retraction are relatively rare Since sides of torn portion maintain capsular continuity and minimal retraction, a direct end to-end suture may be utilized. A With shoulder in abduction, tendon approximated to greater tubercle and laced into apposition with denuded bone by fascia lata or silk. B, Operation completed. (From Wilson, P D. J A. M. A. 96 433, 1931)

A bony channel is next formed along the anatomic neck adjacent to the proximal edge of the greater tuberosity and four to seven holes, three-sixteenths inch in diameter are drilled from the lateral side of the humerus into this channel. With the shoulder abducted the tendon is placed in the channel and laced in position with a strip of fascia lata or silk. The acromioclavicular joint is approximated and held by a No 2 chromic catgut suture through holes drilled adjacent to the joint

After Treatment.—The arm is placed at 90 degrees' abduction and immobilized for a period of three to four weeks At that time the osteotomy of the acromion process should be healed

Longitudinal Rents

Pure vertical rents or longitudinal splits in the axis of the cuff fibers, take place in relatively normal tendons, i.e young individuals whose tendons are sufficiently strong to withstand transverse tears These lesions are located at the junction of the subscapularis tendon and the supraspinatus tendon i e through the level of the coracocapsular ligament. McLaughlin states that the

mitted at once though active elevation is generally postponed until the third to the seventh week The rate of increase of movement should be supervised by the surgeon

In order to understand the basis of Laurence Jones treatment of complete ruptures we should digress and explain his concepts of the anatomy of the shoulder joint It is his contention that movement of the shoulder depends entirely upon two distinct muscle systems one set fixes the glenoid, the other the head of the humerus effort increasing the demand The latter function is carried out by capsular muscles namely the subscapularis anteriorly the supraspinatus muscle superiorly and the teres minor infraspinatus muscles acting as a single component posteriorly The combined weight of these three capsular components is slightly more than that of the deltoid In

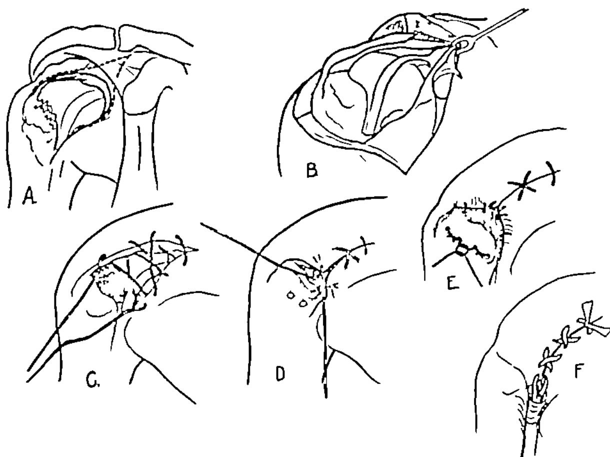
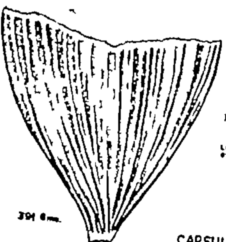


Fig. 874—McLaughlin technic of repair of crescentic rupture through musculotendinous cuff. *A* Dotted lines indicate amount of damaged tissue excised residual defect simulates an isosceles triangle. *B* After exposure by transacromial approach. *C* Placement of shoelace suture stippled area indicates portion of humeral head denuded of cartilage for reinsertion of tendon. *D* Suture pulled tight, up to but not past point of tension, with arm at side. Holes drilled through tuberosity for sutures. *E* Additional sutures stabilize edges of flap. *F* Small tears near bicipital groove may be obliterated by autogenous suture using split biceps. (From McLaughlin H. L. Am. J Surg. 74: 282, 1947)

a sense they serve as antagonists to the deltoid preventing the tendency of the larger muscles to produce abnormal movements of the shoulder joint, or luxation. The frail member of this triad is the supraspinatus muscle which weighs approximately one-seventh of the total weight of the capsular muscles. It is therefore a fallacy to assign to this one small muscle so far as strength is concerned the superlative role in muscle function with which it has been accredited in past literature This fallacy has masked a fundamental concept which Laurence Jones has pointed out namely action of the small supraspinatus tendon could hardly be responsible solely for the loss of abduction



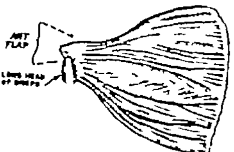






Fig. 375.—Combined weight of three capsular components is slightly more than that of deltoid which weighs approximately one-seventh of total weight of capsular muscles. Frail member of this triad is supraspinatus muscle, Loss of action of small supraspinatus tendon alone could hardly be responsible for loss of abduction which frequently follows interruption of its continuity. Size of anterior flap from subscapularis and posterior flap from infraspinatus-teres minor outlined as utilized in Jones tendoplastic procedure. Courtesy of Dr Laurence Jones.)

which frequently follows the interruption of its continuity Anatomic dissections reveal that the more powerful anterior and posterior capsular muscles pull not only against their bony insertion but against each other through the central link of the entire conjoined tendon, the supraspinatus tendon This fact led Laurence Jones to the conclusion that interruption of the central link produced inaction of the subscapularis muscle anteriorly, and the infraspinatus-teres minor muscle posteriorly

These anatomic and physiologic fundamentals were substantiated clinically by the re-establishment of this same relationship of the three component parts of the capsular muscles following resection of the head of the humerus for comminuted fractures, or comminuted fracture-dislocations (p 472) By applying these concepts to rupture of the supraspinatus tendon reinserting the three muscles at a lower point and linking them together on the outside the normal relation and function is restored the muscles again pull against each other aside from their bony insertion thus substituting for the loss of the supraspinatus tendon as a central link or connecting link of the anterior and posterior components of the capsular muscles.

The McLaughlin procedure described above lends credence to this basic principle of restoration of capsular continuity although his method of operative repair differs rather radically from that of Laurence Jones In the latter procedure two flaps are borrowed one from the infraspinatus and the other from the subscapularis muscle no attempt being made to recover the supraspinatus tendon Perhaps a small amount of muscle power is lost by this procedure though postoperative complications attendant upon attempts to recover and resuture this tendon into the insertion are avoided

Prior to operation a properly fitted abduction humerus splint should be available which will maintain the shoulder in 135 degrees abduction. To provide adequate exposure of all aspects of the joint the patient must be placed on his side with the injured shoulder uppermost A forearm assistant must be available whose sole task is to move the shoulder about in such a way as to permit adequate exposure for both diagnosis and operative treatment and to maintain the shoulder in a fixed position during suture of the flaps.

Multipurpose Plastic Repair (Laurence Jones) —The shoulder joint is exposed by a complete Cubbins incision (p 155) a small fringe being left attached to the acromioclavicular arch to facilitate resuture of the deltoid. The anterior two-thirds of the deltoid muscle is separated bluntly from the underlying structures and retracted laterally and downward In the presence of large scale tears of the capsule (or for habitual dislocation) adequate exposure of the infraspinatus or posterior groups necessitates rather extensive retraction of the deltoid flap and rotation of the shoulder internally to the limit. Conversely before mobilization of the anterior flap the arm must be externally rotated to the extreme limit for visualization of the subscapularis. To create the posterior flap a one-inch incision is made along the posterior vertical line of the greater tuberosity At each end of this incision, the tendinous fibers are divided in line with their axis. The flap is undercut, mobilized and secured by a clamp The approximate size of this flap in relation to the entire posterior capsular tendon is illustrated in Fig 875 The arm is then rotated externally to the limit. A one-inch incision is made through the upper portion of the subscapularis tendon adjacent and parallel to the anterior border of the bicipital group This flap is mobilized by two parallel incisions in line with the fibers as for the posterior flap

FIXATION OF TRANSPLANTED FLAPS

INTERLOCKING (OUTSIDE) BUTTRESS SUTURES

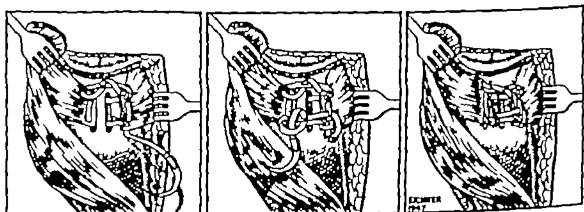


Fig. 576.—Jones tendoplastic procedure. For relative size and location of anterior and posterior flaps, see Fig 575. (Courtesy of Dr Laurance Jones.)

To prepare the site of implantation into the humerus, two parallel slots are created on the upper lateral surface of the bone, and the two are connected by a medullary undercut. With a fascial stripper, two appropriate lengths of fascia lata are then removed from the lateral aspect of the thigh. The fascial sutures are affixed to a Gallie fascia needle and placed in the ends of the anterior and posterior flaps respectively. The anterior subscapularis will always be short. There is no need, however, for lengthening or advancement as the fascial suture, by its very autoplastic fascial composition, serves as a graft and makes further repair of the defect or the deficiency unnecessary. The flaps are fixed as illustrated in Fig. 876. Jones points out that the reinforcing outside buttress sutures are of considerable importance but may be varied according to the wishes of the surgeon. During the placement of the sutures and the implantation of the flaps into the humerus, the extremity must be maintained in neutral rotation and at 135 degrees' abduction. Finally, the deltoid is resutured and the skin closed.

After Treatment.—(See p. 472.)

Rupture of the Biceps Muscle

In incomplete tear of the biceps muscle, conservative measures, such as a Velpeau dressing with the elbow flexed to the Jones position, may suffice. If a sulcus is definitely palpable, however, or if the tear is of several weeks' duration, operative treatment is indicated.

Technic.—To prevent adhesion of muscle to skin, an anterolateral incision is made parallel with the lateral border of the biceps muscle and adjacent to the sulcus. The ruptured muscle is approximated with interrupted mattress sutures of medium silk.

For extensive or neglected tears, Gilcreest supplements this procedure by suture of a layer of fascia lata across the defect. In neglected tears, the ends of the muscles usually are involved in extensive fibrosis and must be freshened before suture.

After Treatment.—A Velpeau dressing is applied, maintaining the elbow in flexion. Active and passive exercises are instituted after three weeks.

Rupture of the Biceps Brachii Tendon

According to Gilcreest, of all ruptures involving the biceps brachii muscle over 50 per cent take place through the tendon of the long head. The tear usually is more or less transverse and is located just distal to the point of entrance of the tendon into the bicipital groove. In the majority of the remaining number of ruptures, the tendon is avulsed at its attachment to the glenoid or at the musculotendinous junction. A few ruptures involve the tendon of the short head, the muscle proper, or the distal tendon of the biceps brachii.

The method of repair should be chosen according to the extent of the pathologic changes in the tendon. If the rupture is extra-articular, the tendon ends should be approximated, if possible, unless the pathologic condition will preclude satisfactory union and subsequent function.

Technic.—Through an incision four inches in length on the anterior aspect of the arm, dissection is carried between the deltoid and pectoral muscles down to the head of the humerus (p. 154). By rotation of the arm, the bicipital groove with the biceps tendon is brought into view. Usually, the proximal end of the tendon is not retracted and may be found just at the lower end of



Fig. 877.—Rupture of biceps.

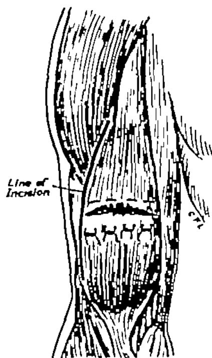


Fig. 878.—Rupture of belly of biceps muscle repaired with interrupted mattress sutures of silk.

the groove, otherwise the roof of the groove is incised and dissection extended upward until this end of the tendon is discovered On the other hand the distal end of the tendon is generally retracted by contracture of the biceps muscle but may be located by dissection distally in some cases, dissection must be carried down to the middle of the arm Both ends of the tendon are freed With braided silk a continuous suture is now made in the proximal segment beginning at the end and passing up the outer border a distance of one inch then down the inner border to the end again In like manner, a second suture is inserted through the end of the distal fragment With the elbow in flexion these sutures are then pulled sufficiently tight merely to approximate the ends of the tendons. If the suture is tied too tightly, the con striction of the tendons will lead to aseptic necrosis and recurrence of the separation.

If end to-end apposition cannot be accomplished with the suture, a tendon or fascial transplant may be utilized In the latter event, the transplant is sutured to the lower segment with interrupted sutures of silk sufficient trac tion is made to approximate the ends as closely as possible and the trans plant is attached to the upper segment

After Treatment.—The extremity is immobilized in a Velpeau dressing with the elbow acutely flexed this will prevent tension from abduction of the shoulder or extension of the elbow After three weeks, passive motion is begun cautiously together with physical therapy to increase the range of motion in the shoulder and elbow No attempt is made to flex the elbow actively for a minimum period of eight weeks.

As suggested by Gilcreest intra-articular ruptures and avulsions from the glenoid are best repaired by transplantation of the tendon that it may arise in common with the short head of the muscle from the coracoid process of the scapula. If the tendon is not of adequate length to permit its attachment to the coracoid process, the segment is sutured to the short head of the biceps muscle or attached to the humerus through holes drilled in the sides of the bicipital groove

Avulsion or Rupture of the Lower Tendon of the Biceps Brachii Muscle

Guibal and Gentin report two cases of rupture of the distal tendon of the biceps brachii muscle For repair of this lesion Kirschner fixed the tendon to the anterior surface of the radius. Although this results in a loss of the supinator power of the biceps, function is nevertheless satisfactory These authors preferred Schmieden s method wherein the tendon of the biceps is sutured to that of the brachialis anticus near its insertion into the ulna, the vessels and nerves passing between the brachialis behind and the biceps in front. Dobbie reviewed twenty four previously reported cases and fifty-one unreported cases which he collected from forty surgeons. He feels that rupture of this tendon is rare yet not so uncommon as is suggested by the few cases described in the literature In his opinion operative repair is necessary to restore function Flexion of the elbow by the biceps is more important than its function as a supinator as the action of the biceps is not essential for supination He points out the hazards of reinsertion of the biceps tendon into the radial tubercle Although this is best from the theoretical point of view practically function is equally as good following insertion of the ten don into the ulna either directly or indirectly as into the tendon of the brachialis,

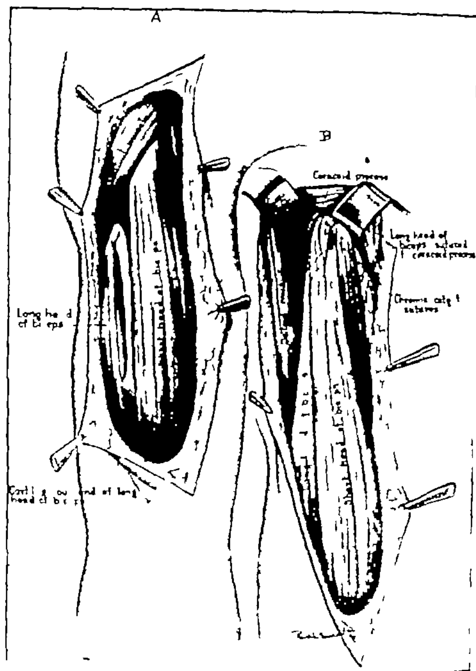


Fig. 879.—A Avulsion of long head of biceps from cartilaginous lip of glenoid. B Long head of biceps sutured to coracoid process and to upper fibers of short head. (From Gilcreest, E. L. Surg. Gynec. Obst. 58: 322, 1934.)

Rupture of the Extensor Pollicis Longus Tendon

Rupture of the extensor pollicis longus tendon is an infrequent complication of Colles fracture occurring three weeks to three months after injury. Whether there is a partial tear of the tendon at the time of fracture, or degenerative changes develop from tenosynovitis after the fracture, is unknown. The point of rupture generally is at the groove in the radius, and may be detected by palpation. An inability to extend the distal phalanx of the thumb is indication for operation.

Technic.—The rupture is exposed through a two-inch incision. If the proximal segment of the tendon is retracted the incision must be extended

proximally until its end is found The lower segment does not retract and is easily located All scar tissue is excised from the ends, and the tendon is united by purse string or mattress sutures as in rupture of the long head of the biceps muscle If end to-end apposition is impossible the gap must be filled by a free tendon transplant When intact the sheath should be closed with No 000 plain catgut on a fine cutting needle and the tendon replaced in the radial groove to preserve its normal mechanical action

After Treatment.—The thumb is held in full extension by means of a metal splint or cast At the end of three weeks active and passive motion and physical therapy are instituted

Avulsion of the Extensor Digitorum Communis Tendon (Mallet Finger)

Avulsion of the extensor digitorum communis, resulting in a drop or mallet finger is usually observed on the right hand and more often involves the long finger The avulsion may or may not be associated with a chip fracture at the tendinous insertion into the distal phalanx According to Bunnell the condition is produced by sudden over flexion of the distal joint of the finger as by a blow from a baseball by stubbing or being caught in a door

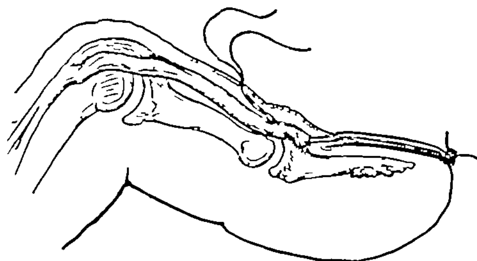


Fig. 880.—Bunnell method of using stainless steel wire for late repair of insertion of extensor tendon. Pull-out wire suture fastened distally to fingernail. (From Bunnell, S.: Surgery of the Hand Philadelphia, 1944 J B Lippincott Co.)

Bunnell also states that an injury of no more than one week's duration may be treated successfully by conservative means. The finger is placed in a small cast with the distal joint in hyperextension. The middle joint is placed in flexion, as this position permits 3 mm of slack in the extensor tendon. Conservative treatment may likewise be employed if the patient is observed during the second week the results however may be questionable. After the second week conservative treatment is not recommended, though a good result may be expected from surgery

Technic (Bunnell).—The avulsed tendon is exposed by an L-shaped incision crossing just proximal to the distal joint. A meticulous technic is essential as the skin is thin and any unnecessary trauma may cause the tendon to become adherent to the end of the middle phalanx, leading to a loss of motion. A No 35 removable stainless steel pull-out wire suture is used in order to minimize any reaction about the end of the tendon. The suture is spliced into the tendon and the pull-out wire inserted as shown in Fig 880

The suture emerges through the skin and is tied through a hole in the end of the nail, as illustrated. The finger is then immobilized in a cast with the distal joint in extension and the middle joint in flexion.

After Treatment.—*The wire suture is removed at the end of three weeks, though the cast immobilization is maintained for five weeks. Thereafter active motion is gradually increased*

SUTURE OF SEVERED TENDONS

Tendons are usually severed by sharp materials, as a knife or glass. In this event, the wound is relatively clean and, if the patient is seen within twelve hours after injury, may be sutured primarily

In other cases, severed tendons are associated with extensive, macerated wounds or compound fractures, which are potentially infected, particularly if twelve hours have elapsed since the original injury Painstaking atraumatic technic and a careful débridement of all devitalized tissues will aid in controlling infection. No attempt should be made to suture the tendons, rather, the skin and subcutaneous structures should be closed as completely as possible, with a minimum amount of suture material. Adequate drainage should then be established. Secondary closure or skin grafting may supplement this procedure later Several months after healing is complete, the wound may be reopened for repair of the tendons either by direct suture of the severed ends (p 107), or by tendon transplants. As a rule only the latter method is feasible because of the excessive contracture

DISPLACEMENT OF TENDONS

Displacement of the Peroneal Tendons

Displacement or dislocation of tendons is by no means a common occurrence The peroneal tendons, however, more than any others, are subject to this abnormality A congenitally shallow groove or complete absence of the groove on the external malleolus is responsible for the condition the displacement may be apparent at birth, or may be induced by trauma. The tendons are dislodged from the groove on the posterior surface of the external malleolus and lie obliquely over the lateral surface of the lower third of the fibula. Since the fulcrum of pull is lost, mechanical efficiency may be materially impaired

Correction is accomplished by the formation of a groove behind the external malleolus, replacement of the tendons in this groove, and repair or reconstruction of the retinacula to maintain the tendons in place. The superior retinaculum is a strong fascial band which passes from the external malleolus across the peroneal tendons to the outer side of the os calcis the inferior retinaculum holds the tendons against the lateral surface of the os calcis anteriorly

If the displacement is associated with paralytic calcaneovalgus foot, correction of the deformity is sufficient (see pp 1320 1326)

Technic—A longitudinal incision is made over the posterior aspect of the lower third of the fibula and the lateral border of the foot, to the cuboid bone. The posterior edge of the incision at the external malleolus is dissected away superficially and the deep fascia incised to form an ample flap with its base at the tip of the external malleolus. The intact sheaths and tendons of the peroneal muscles are retracted anteriorly With an osteotome, a groove is made in the posterior border of the external malleolus and the peroneal

tendons are placed in this groove The fascial flap is next brought over the tendons and stitched to the remains of the superior peroneal retinaculum or to the periosteum or soft tissue on the lateral side of the os calcis, thus maintaining the tendons in normal position

If the deep fascia is deficient, the retinaculum is reformed by a strip of fascia lata two and one half inches long and one fourth inch wide taken from the thigh The anterior extremity of this strip is drawn through a hole drilled in the external malleolus and sutured to itself The other end is brought across the peroneal tendons in the newly formed groove and sutured to the soft tissues posteriorly on the lateral border of the os calcis.

The deep fascia is not closed The superficial layer is sutured with No 0 plain catgut and the skin with silk

After Treatment.—By means of a splint or cast the foot is immobilized in slight eversion and at an angle of 90 degrees to the leg The apparatus may be discarded and walking resumed after one month

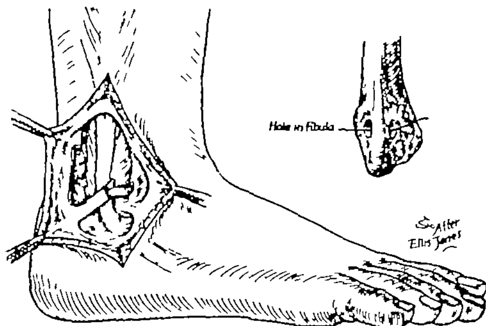


Fig. 881.—Operation of Ellis Jones for displacement of peroneal tendons Check ligament formed by segment of tendo achillis inserted through hole drilled in external malleolus. (Redrawn from Jones Ellis J Bone & Joint Surg. 14: 574, 1932.)

Technic (Ellis Jones) —An incision two inches in length is made posterior to the external malleolus. Without disturbing their sheaths, the peroneal tendons are retracted into their normal anatomic relations with the external malleolus. The tendo achillis is exposed and a tongue-shaped flap two by one-fourth inches, is dissected down from its lateral border and left attached at the calcaneal insertion. Through the lateral malleolus, which is next exposed, a hole is drilled in an anterior posterior direction. The free end of the flap from the tendo achillis is drawn through the hole and sutured to itself and to the periosteum.

After Treatment.—(See above.)

Displacement of the Biceps Brachii Tendon From the Bicipital Groove

Dislocation of the biceps brachii tendon gives rise to a symptom complex referred to by Gilcreest as the "bicipital syndrome." The treatment is surgical.

At times, the dislocation may be reproduced by the following test, verifying the diagnosis: With a five-pound dumbbell in each hand, the patient brings his extended arms to the overhead position, holding them in extreme external rotation. The examiner places his fingers on the long head of the biceps muscle as the patient lowers his outstretched arms to the side in the coronal plane. When the arms reach an angle of 110 to 90 degrees, a snap may be definitely audible and palpable in the top of the injured shoulder, and a sharp pain is experienced in both the shoulder and the region of the bicipital groove.

Abbott and Saunders report six cases with their operative findings. They describe the function of the long head of the biceps, and feel that the tendon is preferably maintained in its anatomic position, if possible especially if this injury is associated with other lesions about the shoulder such as a rupture of the supraspinatus tendon These authors state, however that no rules can be formulated as to the most suitable procedure In uncomplicated cases, fixation of the tendon in the bicipital groove is probably the quickest and best method of repair and in their experience has been followed by good function of the shoulder If other lesions are present, fascial repair of the roof of the bicipital groove is necessary

Technic (Gilcreest).—The bicipital groove is approached through an anterior incision between the deltoid and pectoral muscles and, if necessary the groove is deepened. The long head of the biceps brachii tendon is then located, replaced in the groove, and secured by suture of the transverse humeral ligament. Should there by any doubt that the tendon will remain in the groove, the tendon is divided high instead, transplanted into the tendinous origin of the short head of the biceps brachii and fixed to the coracoid process.

Gilcreest reports good results following the latter method and feels that transplantation is perhaps better than replacement of the tendon in the bicipital groove

After Treatment.—A Velpeau dressing is applied and allowed to remain undisturbed for two weeks.

STENOSIS OF TENDON SHEATHS

This condition generally involves the sheaths of the abductor pollicis longus and extensor pollicis brevis tendons as they pass through a common groove on the dorsum of the radius. The flexor pollicis longus tendon may also be affected following repeated pressure, such as that caused by frequent use of scissors. Operation gives prompt relief of symptoms.

Stenosis of the Sheaths of the Abductor Pollicis Longus and Extensor Pollicis Brevis Tendons

Diack and Trommald are of the opinion that this condition is not as uncommon as believed rather the diagnosis is often missed. Pain about the styloid of the radius, often with radiation up the forearm and into the thumb is a diagnostic feature The patient often complains of 'dropping things. Adduction (ulnar deviation) of the wrist and abduction of the thumb are painful. Tenderness and a firm swelling are present over the styloid process of the radius. Nonoperative treatment consists of immobilization of the thumb in abduction by means of a plaster cast for a period of six weeks This is said to give relief in about 70 per cent of cases. Diack and Trommald have found

operation universally curative and, because of its simplicity and the short convalescent period consider it the treatment of choice in all cases

Technic.—A longitudinal incision 4 cm in length is made over the styloid tip and dissection is carried down to the affected tendon sheath In the majority of cases, only a simple incision of the tendon sheath is necessary, or, the thickened roof of the tendon may be excised at the point of constriction No effort is made to reconstruct the tendon sheath The wound is closed and a light pressure dressing is applied, holding the thumb in moderate abduction.

After Treatment.—Mild active motion is instituted after two or three days, and is gradually increased following healing of the wound.

Stenosis of the Sheath of the Flexor Pollicis Longus Muscle

Technic.—The tendons are exposed through a lateral incision at the distal border of the thumb The point of constriction usually is found adjacent to the metacarpophalangeal joint. Treatment is carried out as described for stenosis of other tendon sheaths.

LESIONS OF THE TENDON SHEATHS

Lesions of the tendon sheaths are similar to those which involve the synovial lining of joints namely, pyogenic infections, tuberculosis, tumors, diseases of syphilitic origin, and others. Operative treatment centers principally upon pyogenic infections of the tendon sheaths of the forearm and hand. The procedures for drainage although not difficult technically, must be exact (Fig 167) Reference may be made to the works of Doctors Allen B Kanavel Deryl Hart and Sterling Bunnell.

HERNIA OF MUSCLE

Hernia of muscle through a defect in the sheath as a result of trauma is of relatively rare incidence. The hernia presents superficially as a *tumor* which contracts and expands upon contracture and relaxation of the affected muscle. The most common site is the tibialis anticus though we have observed gross herniation of the vastus lateralis muscle through a defect in the fascia of the thigh following excision of fascia lata As a rule the lesion is not disabling, especially if large and surgery is unnecessary occasionally however pain may be associated requiring operative repair

A defect of moderate size may be enlarged to permit sliding of the muscle within the deep fascia. Since suture of the deep fascia may cause pressure necrosis, a medium sized or large hernia should be repaired with caution. The defect must be closed without tension, even though removal of an elliptical section of the muscle is necessary In the event the hernia can be closed without constriction of the underlying muscle, the following technic may be employed.

Technic.—A longitudinal incision is made over the herniated muscle, which will be observed protruding through a defect in the fascia lata. The borders of the fascial defect are thickened by fibrosis, constituting the hernial neck. An elliptical incision is made around this ring and extended through the fascia three inches above and three inches below The adjacent fascia is then dissected free on both sides, the edges overlapped and stitched with mattress sutures. Thus, two layers of fascia are placed over the site of the previous hernia.

TENNIS ELBOW

The exact pathology and etiology of tennis elbow is unknown. According to the most widely accepted explanation the affection is a partial tear of the conjoined tendon, principally of the extensor carpi radialis brevis muscle, or a tear between the tendinous origin of the muscle and the periosteum, with a subsequent traumatic periostitis from muscular contractures. Rarely inflammation of the radiohumeral bursa, which lies between the conjoined tendon and the radiohumeral joint, produces this entity Cyriax collected only twelve *cases of radiohumeral bursitis from the literature over a period of fourteen* years.

In the majority of cases the injury responds to rest and physical therapy Recovery, however may be somewhat prolonged by this method of treatment.

Marlin, Mills, and Cyriax have reported satisfactory results with a material decrease in the period of disability by manual stretching of the extensor muscles. The partial tear of the conjoined tendon is converted into a complete tear, the tendon being detached from the chronically inflamed periosteum to which it is adherent. We have not had sufficient experience with this procedure to judge its merits

Technic (Cyriax).—With the elbow at a right angle and the forearm in supination, the anterior part of the lateral epicondyle is massaged for a period of five to ten minutes. The elbow is next fully extended, if possible with the forearm in supination, then forcibly adducted with a sudden movement, one hand being held on the inner side of the elbow and the other on the outer side of the wrist to produce a position of cubitus varus. This maneuver is repeated three times weekly Cyriax has found that four treatments are generally sufficient to give relief.

Technic (Mills).—With the wrist and fingers flexed and the forearm fully pronated the elbow is forced into extension while firm pressure is made with the thumb over the tender spot on the external epicondyle.

Carp has successfully treated four cases of tennis elbow following radiohumeral bursitis by rupturing the bursa with digital pressure in a manner similar to that employed for ganglion.

Surgical Procedures for Tennis Elbow

Osgood Dittrich and Kleinberg have excised radiohumeral bursae, with immediate and lasting relief of symptoms.

Technic (Osgood).—An oblique incision one and one-half inches long is made over the radiohumeral joint from above the external epicondyle well down over the head of the radius. The conjoined tendon of the extensor muscles is split, and the bursal sac, if found is removed. If no definite bursa is found the tissue between the conjoined tendon and the epicondyle is excised.

In the light of more recent knowledge the most satisfactory surgical treatment is the operation described by Hohmann.

Technic (Hohmann).—After exposure of the external epicondyle, the origins of the conjoined tendons on the anterior surface of the epicondyle are divided transversely At the same time, the area between the conjoined tendon and the radiohumeral joint may be inspected and the radiohumeral bursa removed, if present.

Hohmann reports satisfactory results in fourteen of fifteen patients treated by this method.

GANGLION

A ganglion is a small cystic structure formed by an extension of synovial lining from an adjacent joint or tendon sheath, or as a result of a degenerative process in the connective tissue The dorsum of the scaphoid and semilunar bones is the most common site The cyst may be attached to an adjacent tendon sheath or to the dorsal capsule of the wrist joint by a pedicle, in which there may or may not be a connecting lumen There are two methods of treatment forceful subcutaneous rupture and excision.

Subcutaneous rupture is accomplished by the following procedure

Technic.—The wrist is forcibly flexed to make the tumor more prominent and sharp pressure is exerted over the mass with both thumbs. Often the tumor will disappear immediately The classical though rather unscientific method of striking the ganglion with a book will also effect rupture.

After Treatment.—A splint (p 70) is applied to hold the wrist in dorsal flexion At the end of three weeks the splint is replaced by a soft leather wrist corset which permits a fair range of motion The corset may be discarded after two months.

Subcutaneous rupture is not a dependable method of cure as the ganglion frequently recurs. For recurrences, or for a large ganglion of long standing excision is the proper treatment

Although in the majority of cases, removal of a ganglion may be regarded as a minor operation, the patient should be prepared and draped as for major surgery in anticipation of a connection between the cyst and sheath or wrist joint, and the operation preferably should be performed under general anesthesia. We have observed disastrous infections of the sheaths and wrist joint from haphazard excision of a "simple ganglion."

Technic.—A longitudinal or transverse incision is made over the ganglion, of a length to permit clean dissection of the entire mass. The ganglion is incised, the contents evacuated, and the connection to the tendon or joint found if possible, by a small probe The ganglion is then removed by incision around its base. As a rule, this is sufficient should the cyst communicate with a joint or tendon sheath the tract is excised with as much of the adjacent synovial membrane as is accessible. If necessary the incision may be enlarged to expose the joint and a partial synovectomy performed.

After Treatment.—(See above.)

If the entire process is removed, the results usually are excellent otherwise, there may be a recurrence.

TRIGGER, OR SNAPPING FINGER

Tendonitis or tendovaginitis occasionally gives rise to the so-called trigger finger The deformity usually is observed in middle-aged or elderly individuals, and is more common in women than in men. The middle finger is most often affected, generally in the region of the metacarpophalangeal joint. A small nodule or enlargement is found on the flexor tendon where it passes beneath the pulley opposite the metacarpophalangeal joint. The opening in the pulley may be constricted or a portion of the sheath itself may be thickened and constricted and pressing upon the tendon to such a degree as to cause an enlargement of the tendon on each side of the band.

Absolute rest of the finger in the semiflexed position for a period of one month may be sufficient to effect a cure. If not, surgical correction should be undertaken.

Technic—A short, curved incision is made in the palm over the metacarpophalangeal joint and, if necessary, a second short incision is made along the medial side of the proximal phalanx of the affected finger The tendon, annular band and either a nodule or a fusiform enlargement of the tendon, usually the latter are exposed A definite nodule if present, is removed. A fusiform enlargement of the tendon requires splitting of the annular band. Bunnell states that the band should be split through on its lateral side and never on its gliding surface. Care should be taken to avoid the digital nerve.

After Treatment.—A splint or dressing is applied holding the finger in moderate flexion. The wound usually heals within one or two weeks, thereafter active motion of the finger is resumed

References

Abbott, L. C. and Saunders, J B deC. M.: Acute Traumatic Dislocation of the Tendon of the Long Head of the Biceps Brachii; Report of 6 Cases With Operative Findings, Surgery 6 817 1939

Armstrong J R: The Supraspinatus Syndrome Lancet 1: 94 1947

Bertwistle, A. P: The Role of Chemiotaxis in Bone Growth, London, 1937, Henry Kimpton.

Björkroth T: A Short Review of the Pathology and Clinical Symptoms of Rupture of the Biceps Tendon Internat Abstr Surg 65 131 1937 (Abst. from Acta chir. Scandinav 79 230 1937)

Bosworth D M: An Analysis of Twenty Eight Consecutive Cases of Incapacitating Shoulder Lesions, Radically Explored and Repaired, J Bone & Joint Surg. 22. 369, 1940

Bosworth, D M: Supraspinatus Syndrome: Symptomatology Pathology and Repair J A. M. A. 117 422, 1941

Bunnell S. *Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.*

Bunnell, Sterling: Repair of Nerves and Tendons of the Hand, J Bone & Joint Surg. 10: 1 1928.

—: Surgery of Tendons, Dean Lewis Practice of Surgery Vol. III Chap. 5, Hagerstown, Md., W F Prior Co., Inc.

—: Contractures of the Hand From Infections and Injuries, J Bone & Joint Surg. 14: 27 1932.

Carp, Louis Tennis Elbow (Epicondylitis) Caused by Radiohumeral Bursitis, Arch. Surg. 24 905, 1932.

Codman, E. A.: Rupture of the Supraspinatus Tendon Surg Gynec. Obst. 52 579, 1931.

Codman, E. A: Rupture of the Supraspinatus, Am. J Surg 42 603, 1938.

Codman, E. A. and Akerson, I. B.: The Pathology Associated With Rupture of the Supraspinatus Tendon, Ann. Surg. 93 348, 1931

Conwell, H E. Subcutaneous Rupture of the Biceps Flexor Cubiti, J Bone & Joint Surg 10 788 1928

Conwell, H. E., and Alldredge R. H.: Ruptures and Tears of Muscles and Tendons, Am. J Surg 35 22 1937

Coues, W P: Epicondylitis (Franke) or Tennis Elbow Boston M. & S. J 170 461, 1914.

Cyriax, J H. The Pathology and Treatment of Tennis Elbow J Bone & Joint Surg. 18. 921, 1936.

Davidson, W T Rider s Tendon Rupture of the Adductor Tendons of the Thigh, Surg Gynec. Obst. 26 192, 1918.

Davis, T W., and Sullivan J E.: Rupture of the Supraspinatus Tendon, Ann. Surg 106. 1059 1937

Diack A. W., and Trommald J P: De Quervain s Disease; Frequently Missed Diagnosis, West. J Surg 47 629 1939

Dittrich, R. J Radiohumeral Bursitis (Tennis Elbow), Am. J Surg 7 411, 1929.

Dobbie R. P Avulsion of the Lower Biceps Brachii Tendon; Analysis of 51 Previously Unreported Cases, Am. J Surg 51 662, 1941

Eckhoff Nils L. Tourniquet Paralysis. A Plea for the Extended Use of the Pneumatic Tourniquet, Lancet 2. 343, 1931.

Elmslie, R. C. Calcareous Deposits in the Supraspinatus Tendon, Brit. J Surg. 20: 190 1932.
Fievez: Twenty Two Cases of Intracapsular Rupture of the Tendon of the Long Head of the Biceps Brachialis Internat. Abstr Surg 51 505 1930. (Abst. from Bull. et mém. Soc. nat de chir 56: 554 1930)
Friedman, M S.: Xanthoma of the Achilles Tendon J Bone & Joint Surg 29 760, 194?
Gallie, W E., and LeMesurier, A. B.: The Late Repair of Fractures of the Patella and of Rupture of the Ligamentum Patellae and Quadriceps Tendon, J Bone & Joint Surg 9 47, 1927
Ghetti, L.: A Contribution to the Study of Subcutaneous Rupture of the Tendinous Insertions of the Biceps Brachialis, Internat. Abstr Surg 25: 5??, 193? (Abst. from Chir d. org di movimento 17 137, 1932.)
Gilcreest, E. L.: The Common Syndrome of Rupture Dislocation and Elongation of the Long Head of the Biceps Brachii, Surg Gynec. Obst. 58 322, 1934.
— Dislocation and Elongation of the Long Head of the Biceps Brachii Ann Surg 104 118, 1936.
Guibal, J., and Gentin, R.: Traumatic Disinsertion of the Lower Tendon of the Brachial Biceps, Internat. Abstr Surg 57 44 1933
Guibal and Ortscheit: Two Cases of Disinsertion of the Tendon of the Insertion of the Biceps, Internat. Abstr Surg 51 505 1930. (Abst. from Bull. et mém. Soc. nat. de chir 56 554 1930)
Haldeman, K. O., and Soto-Hall, Ralph: Injuries to Muscles and Tendons, J A M. A. 104: 2319 1935.
Hart, Deryl Surgery of the Hand, Dean Lewis' Practice of Surgery, Vol. V, Chap 10, Hagerstown, Md., 1935 W F Prior Co., Inc.
Hodgson, N Volkmann's Ischaemic Contracture Treated by Transplantation of the Internal Epicondyle Brit. J Surg 17 317, 1929
Hohmann: Das Wesen und die Behandlung des sogenannten Tennisellenbogens, München. med. Wchnschr 80 250 1933.
Howorth, M. B.: Calcification of Tendon Cuff of Shoulder, Surg., Gynec. & Obst. 80 337, 1945.
Inman, V T., Saunders, J B., deC. M., and Abbott L. C. Observations on the Function of the Shoulder Joint, J Bone & Joint Surg 26 1 1944
Jones, Ellis Operative Treatment of Chronic Dislocation of Peroneal Tendons, J Bone & Joint Surg. 14 574 1932.
Jones, L. Complete Rupture of the Supraspinatus Tendon Simplified Operative Repair Arch. Surg 49 390, 1944
Jones, L. The Shoulder Joint—A Multipurpose Plastic Repair To be published.
Jones, L.: The Shoulder Joint—Observations on the Anatomy and Physiology, With Analysis of Reconstructive Operation Following Extensive Injury, Surg., Gynec. & Obst. 75 433, 1942.
Jones, Sir Robert: Volkmann's Ischaemic Contracture, With Special Reference to Treatment, Brit. M. J 2: 639 1928
Jones, S. G : Volkmann's Contracture J Bone & Joint Surg 17: 649 1935.
Jones, S. G., and Cotton, F J Ischemic Paralysis of Leg Simulating Volkmann's Contracture, J Bone & Joint Surg 17 659, 1935.
Kanavel, Allen B Infections of the Hand, Philadelphia, 1933 Lea & Febiger
Keyes, E. L.: Observations on Rupture of Supraspinatus Tendon, Ann. Surg. 97 849 1933
Koch, S. L.: Acute Rapidly Spreading Infections Following Trivial Injuries of the Hand, Surg Gynec. Obst. 59 277 1934.
McLaughlin, H. L.: Common Shoulder Injuries, Am. J Surg 74 282 1947
McLaughlin, H. L.: Lesions of the Musculotendinous Cuff of the Shoulder; Observations on the Pathology Course and Treatment of Calcific Deposits, Ann. Surg 124: 354 1946.
McLaughlin, H. L. Lesions of the Musculotendinous Cuff of the Shoulder I. The Exposure and Treatment of Tears With Retraction, J Bone & Joint Surg. 26: 31 1944.
McLaughlin, H. L.: Lesions of the Musculotendinous Cuff of the Shoulder, Differential Diagnosis of Rupture J A. M. A. 128 563 1945.
McLaughlin, H. L.: Muscular and Tendinous Defects at Shoulder and Their Repair Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor, Michigan, 1944 J W Edwards.
McLaughlin, H. L.: The Treatment of Injuries to the Shoulder, Am. Acad. Orth. Surgeons, Regional Orthopedic Surgery and Fundamental Orthopedic Problems, Yearbook, Ann Arbor, Michigan 1947 J W Edwards.
Marlin, Thomas Treatment of 'Tennis Elbow Lancet 1 509 1930.
Mason, M. L.: Rupture of Tendons of the Hand. With a Study of the Extensor Tendon Insertions in the Fingers, Surg Gynec. Obst. 50 611 1930
Mason, R. L. Rupture of the Quadriceps Tendon, S. Clin. North America 9: 1467, 1929.
May Hans: Tendon Transplantation in the Hand, Surg Gynec. Obst. 83: 631, 1946.

Mayer Leo Surgery of Tendons, Cyclopedia of Medicine 12 1 1934, Philadelphia, F A. Davis Co.
— Rupture of the Supraspinatus Tendon, J Bone & Joint Surg. 19 640 1937
McMaster P E.: Late Ruptures of Extensor and Flexor Pollicis Longus Tendons Following Colles Fracture, J Bone & Joint Surg. 14 93, 1932.
—: Tendon and Muscle Ruptures, J Bone & Joint Surg. 15 705, 1933
Meyer A. W: Spontaneous Dislocation and Destruction of Tendon of Long Head of Biceps Brachii Arch. Surg 17 403 1928.
Meyerding H W: Volkmann's Ischemic Contracture, J A. M. A 94 394 1930.
—: Volkmann's Ischemic Contracture Associated With Supracondylar Fracture of the Humerus, J A. M. A 106 1139 1936.
Milch, Henry: Repair of Ruptured Quadriceps by Free Fascial Graft Transplant, J Bone & Joint Surg 13 361, 1931.
Mills, G P: The Treatment of Tennis Elbow,' Brit. M. J 1 12, 1928.
Morrison, G M., and Harrison E. K.: Ischemic Paralysis From Pressure of Hematoma, J Bone & Joint Surg 17: 636, 1935.
Osgood, R. B Radiohumeral Bursitis, Epicondylitis, Epicondylalgia (Tennis Elbow) Arch. Surg 4: 420, 1922.
Outland, T A., and Shepherd W F: Tears of the Supraspinatus Tendon, Ann. Surg. 107 116, 1938.
Platt, Harry Observations on Some Tendon Ruptures, Brit. M. J 1 611 1931.
Quénu and Stoïanovitch: Rupture of the Tendon of Achillis, Internat. Abstr Surg. 51 4°1 1930 (Abst. from Rev de chir 48 617 1929)
Smillie I. S.: Mallet Finger, Brit. J Surg. 24 439, 1937
Snoke, P O Myositis Ossificans Progressiva, Am. J Surg 21 111 1933
Steindler A. Orthopedic Operations Springfield, Ill., 1940, Charles C Thomas.
Steinmann F: Unfallmedizinische Studie der Ruptur der langen Bizepssehne, Schweiz. med. Wchnschr 61 1140 1931.
Tutunjian K. H., and Kegerreis, Roy Myositis Ossificans Progressiva, J Bone & Joint Surg 19: 603, 1937
Wagner L. C.: Complete Rupture of Infra Patellar Tendon and Adjacent Capsular Ligaments, Ann. Surg 86: 787, 1927
Wilson C. L.: Lesions of Supraspinatus Tendon; Degeneration, Rupture and Calcification, Arch Surg 46 30 1943.
Wilson Philip D: Complete Rupture of the Supraspinatus Tendon, J A. M. A. 96 433, 1931.
Young F., and Harris, C. T Complete Excision and Reconstruction of Both Achilles Tendons for Giant Cell Xanthoma Surg., Gynec. Obst. 61: 662, 1935.

CHAPTER XXI

AFFECTIONS OF THE SKIN, FASCIAE, BURSAE AND LYMPHATIC SYSTEMS

SKIN PLASTIC PROCEDURES

In orthopedic surgery, skin transplantation is employed (1) to expedite the healing of granulating surfaces, (2) to replace painful, ulcerative or contracted cicatrices, and (3) to substitute normal skin for adherent scars over bones and joints prior to surgery, as a precaution against sloughing of scar tissue and infection following operation Two types of transplants are utilized grafts and flaps.

The term "graft" designates those transplants which are removed entirely from one area to another at a single operation Grafts may be small or large and may include varying thicknesses of the skin, i e., (1) the epidermis and a thin layer of dermis, (2) the epidermis and a thick portion of the dermis, or (3) the full thickness of the skin with a small part of the subcutaneous fat The smallest of these grafts, which may be of any thickness, is popularly known as the "pinch graft" Of the large grafts, the thinnest are called Ollier Thiersch grafts those of moderate thickness, "thick-split grafts," while those of greater depth are known as Wolfe Krause grafts.

Flaps are portions of skin which are undercut and left attached to their normal sites at one or both ends. They may consist of normal tissue advanced from the edges of the wound of single pedicle flaps rotated or advanced from the immediate area of the defect, or of single or double pedicle flaps from a distant region.

Skin transplants may be applied either to granulating surfaces or to fresh operative wounds. The surfaces of granulating wounds should be clean, pink and firm before being covered either excessive or sluggish granulations form a poor field for transplants

In fresh operative wounds, the dissection should be sufficiently extensive to provide a foundation of healthy tissue for the transplant.

Whether the area to be grafted is a granulating surface or a fresh operative wound, the field should be as dry as possible so that the graft may adhere firmly In securing hemostasis, the minimum amount of catgut should be used. For the technic of these plastic procedures the reader is referred to works on plastic surgery

Cicatrix Over the Tibia

Adherent scars over the tibia are common following osteomyelitis compound fractures, burns, and lacerations of the soft parts. These scars become firmly attached to the underlying bone their nutrition is poor and because of their location they are constantly subjected to injury Slight trauma causes a sloughing and ulceration which heals with difficulty Complete removal of the adherent scar and the shifting of adjacent normal skin over the bone is the most satisfactory method of treatment.

Technic.—The entire scar is dissected free and the thickened bone over the front of the tibia is removed. A second incision, usually two inches to the inner border of the tibia, is made parallel to the wound, and the intervening skin and subcutaneous fat down to the deep fascia are raised, forming a double

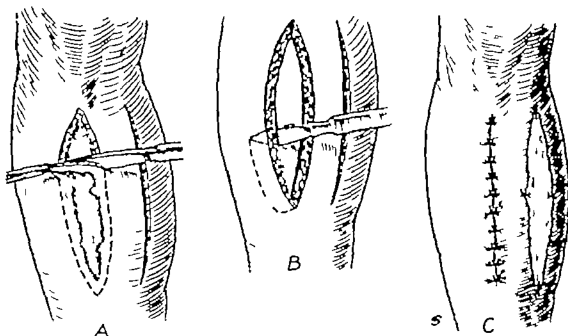


Fig. 812.—Advancing flaps for cicatrix over tibia. *A* Scar tissue excised in elliptical manner to normal skin. Counter incision medial side of leg. *B* shaded area indicates portion of skin to be undercut. *C*, Flap of skin transferred, closing defect over tibia. Defect in counter incision covered with split graft.

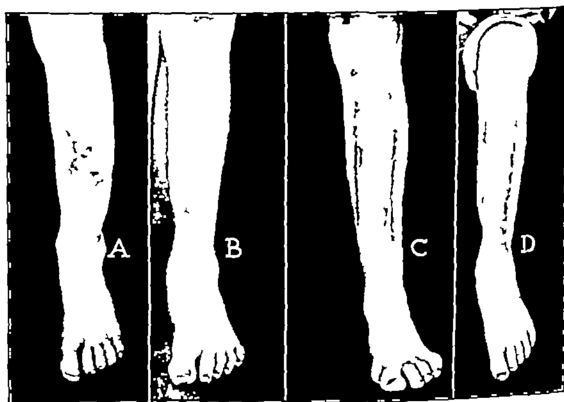


Fig. 813.—*A* Scar over tibia, with old healed ulcers. *B*, *C*, and *D* End result in three patients after tranference of full-thickness double pedicle skin flap over tibia.

pedicle flap This is displaced laterally over the tibia and sutured firmly to the lateral edge of the wound completely covering the exposed bone The raw area on the inside of the calf from which the flap was removed is allowed to heal by granulation or is covered by a thin skin graft taken with a Padget dermatome. The latter is preferable

When the scar is long, extending the full length of the tibia, two flaps are used, one being transferred from the inner side to cover the upper half the other from the outer side to cover the lower half of the defect.

DUPUYTREN'S CONTRACTURE OF HANDS AND FEET

This is a contracture and fibrosis of the palmar fascia that may be bi lateral or unilateral A plantar lesion of one or both feet may be coexistent. Combined palmar and plantar lesions were first noted by Dupuytren There has been scant mention of this association until recently when Luck reported 14 cases.

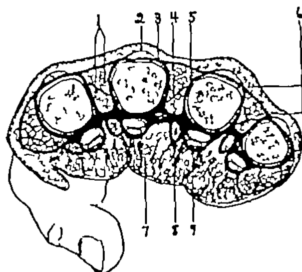


Fig 851.—Cross section of hand just proximal to distal palmar creases, showing extensive system of ligamentous septa and fluted arches in distal half of palm which bind firmly the tendons, palmar fascia, and skin to bones. "Palmar fascia has here fused to the four large arches or pulleys of the flexor tendons and also to the radial side of each, to the fascia forming the four lesser arches of the lumbrical canals. (1) Anterior and posterior interosseus muscles. (2) Extensor tendon. (3) Dorsal aponeurosis. (4) Pre-interosseus fascia. (5) At tachment to metacarpal of dorsal aponeurosis and septa from pre-interosseus fascia. (6) Cleav are spaces between metacarpals and surrounding fascia. (7) Fibrous connections between palmar fascia and skin. (8) Lumbrical canal or lesser arch. (9) Tendon pulley or greater arch. (From Bunnell, S Surgery of the Hand Philadelphia, 1944, J B. Lippincott Co)

The etiology is obscure. Hereditary factors are established in the form of a constitutional predisposition by a defective vasomotor apparatus in the fascia other inciting etiologic factors must be considered particularly chronic inflammation on the basis of either a trophic disturbance or a low grade infec tion. To quote from Luck we may ultimately learn that not one but a great many factors acting singly or in combination can upset the serene tran quility of normal palmar and plantar fascia "

The pathology in either the hand or foot is represented by *cords* or *nod ules* of fibrosis In the late stages of this process microscopic anatomy causes no confusion. Earlier particularly in the *plantar fascia* a mistaken diag nosis of fibrosarcoma may be made, as areas of fibroblasts frequently fail to mature and long retain a superficial appearance of fibrosarcoma. (The reader may refer to the article by Luck for an excellent review of this aspect of Dupuytren s contracture.)

The existence of this lesion in either the hands or the feet calls for examination of the other

Dupuytren s Contracture of the Hands

Contractures of the fingers from fibrosis of the palmar fascia interfere materially with function of the hand, the incidence being as follows, from highest to lowest ring finger, little finger, long finger, index finger and thumb The operation must be performed correctly and with extreme care or good results cannot be expected A dry field must be maintained by means of a tourniquet (p 81) in order to insure removal of all the palmar fascia. The nerves must not be cut nor damaged otherwise serious anesthesia of the fingers will follow Care is taken not to injure the motor nerves to the lumbricales or the nerves to the thenar muscles. Every effort should be made to protect the skin or there may be a slough followed by infection. The palmar fascia should be removed en bloc including the septa connecting the palmar fascia to the sides of the metacarpals the bands running down to the fingers, and the fibers connecting the fascia to the skin.

Technic (Bunnell) —To prevent recurrence of the bands of scar tissue and consequently new contractures, the incision should not be made longitudinally over the lines of the contracture instead, the incision is made parallel to the distal palmar crease at the ulnar border of the hand and curved upward to the base of the palm along the course of the flexor tendon of the little finger This L-shaped incision is reflected upward, the skin being divided from the palmar fascia by sharp dissection Care is taken not to buttonhole the skin. The skin flap is left as thick as possible though all abnormal fascia is removed. Dissection is begun on the ulnar side of the hand and continued across the palm medially At the base of the palm, the insertion of the palmaris longus tendon into the palmar fascia is divided and the entire deep fascia is removed from the palm to the bands running into the fingers. The affected fingers are then opened by midlateral incision the volar digital vessels and nerves are protected and the thickened fascial bands excised. The digital nerves which may be surrounded by a mass of fibrous tissue must next be carefully located. As the dissection progresses across the palm eight septa are encountered between the palmar fascia and the bones. These septa arch over the tendons and thence over the lumbricales, vessels, and nerves, they should be divided deep in the palm without damage of the tendon sheath or the muscles nerves and vessels within the four arches containing these structures The palmar fascia having been completely removed, the tourniquet is released and a pressure dressing applied for five minutes to allow clotting The remaining vessels are ligated with No 0000 catgut. Bunnell uses fine stainless steel wire to close the incision. Three small rubber drains are inserted and a sponge rubber pressure dressing is applied. By means of either a previously prepared dorsal splint or a plaster splint, the fingers are maintained in extension as far as the skin nerves and vessels will permit. Complete extension of the fingers is not attempted immediately after operation unless this can be done with safety

In severe cases, skin grafting may be necessary for closure of the wound. Usually a thick graft removed with a Padget dermatone will suffice. In extreme cases, a tubular pedicle flap must be attached to the ulnar aspect of the hand before operation that it may be ready for transference at the time of the operation.

After Treatment.—*The drains are removed after twenty four hours* Continuous steady pressure is maintained by the pressure dressing for one week, or for two weeks if a skin graft has been applied The palm of the hand is immobilized until the wound is well healed which usually is two weeks Prolonged splinting leads to stiffening of the fingers Motion in the middle and *distal joints of the fingers is allowed for the first week and* encouraged during the second week In the more favorable cases complete flexion may be developed within one month In more severe cases motion may gradually improve for a year



Fig. [illegible]—*A* and *B* Dupuytren s contracture involving fourth and fifth fingers. *C* Slight recurrence of contracture of fifth finger postoperatively

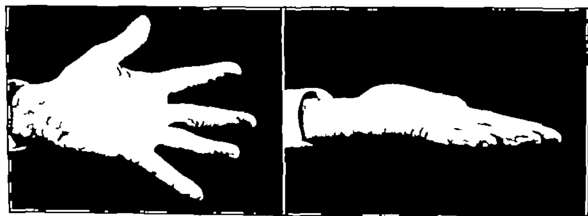


Fig [illegible].—Four years after operation for Dupuytren s contracture. Middle and ring fingers were acutely flexed into palm. Patient now has normal function.

Dupuytren s Contracture of the Feet

The clinical manifestations of fibrosis of the plantar fascia are less dramatic than those of the hands The fibrotic cords and particularly the nodules produce pain and tenderness, not unlike foot strain. Flexion contractures of the metatarsophalangeal joints do not occur though extension may be somewhat limited The pathology is best visualized by dorsiflexion of the toes with the ankle extended.

Treatment consists of excision of isolated large nodules or if the pathology is extensive, a major segment of the plantar fascia is removed. The latter is accomplished through an incision three to four inches in length on the medial aspect of the foot, thereby avoiding a weight bearing portion of the skin. The majority of the lesions is on the medial aspect of the fascia at the level of the scaphoid bone, and extends forward covering the first meta

tarsal bone. The technic of excision is essentially similar to that of the palmar fascia ordinarily, surgery of the fascia will be limited to that portion which can be reached without incision of weight bearing skin.

SNAPPING HIP

Snapping hip is a term used to designate an audible, palpable or visible snap made by the sliding of a tense fascial band over the trochanter as the hip is flexed adducted, or rotated internally This band usually consists of a thickened posterior border of the iliotibial band or anterior border of the insertion of the gluteus maximus muscle. Carrell has reported one case wherein trochanteric bursitis was the responsible agent. Roentgenograms should always be made to eliminate the possibility of osteochondroma of the trochanteric region. In a few cases, intra articular lesions, such as loose bodies or osteochondromatosis, or subluxation associated with paralysis of the muscles of the hip may cause a clicking sensation which is perceptible to both the patient and the examining physician. These lesions must be differentiated from the usual type of snapping hip

Surgical treatment is rarely necessary as the condition is not painful nor disabling Usually after explanation of the source of the disturbance, patients prefer to continue without surgical interference. When the patient desires relief, however or when the condition forms a background for a neurosis, operation may be undertaken The procedure is a simple one and results are excellent in practically every case.

Local anesthesia is preferable, as the tense band is found with difficulty if the muscles are fully relaxed by inhalation anesthesia. Under local anesthesia the patient can voluntarily snap the hip and the band may be easily located by direct vision and palpation.

Technic.—An incision is made in line with the junction of the gluteus medius and tensor fasciae femoris muscles to the posterior border of the greater trochanter thence continued distally in the longitudinal axis of the thigh a distance of four inches. On incising the iliotibial band, a definite, thickened strip may be palpated on its posterior inner surface. This portion is dissected up to the trochanter forming a flap three to four inches in length. The distal end of the tensor fasciae femoris muscle is then freed. The anterior portion of the iliotibial band is next exposed by subcutaneous dissection the posterior half is transferred anteriorly sutured to the fascia on the anterolateral surface of the thigh and fixed by chromic catgut sutures.

Godoy Moreira reported a case wherein the snapping was due to hooking of the posterior margin of the fascia lata over an abnormally large superior margin of the greater trochanter Treatment consisted of resection of a portion of the greater trochanter in addition to the removal of a fibrous mass which arose from the fascia lata opposite the trochanter The patient had an excellent result six years after the operation.

Binnie follows a technic wherein the fascia lata over the greater trochanter is incised, a flap of the periosteum is raised on the greater trochanter by a longitudinal incision, and the posterior edge of the fascia lata sutured to the periosteal flap and to the vastus lateralis muscle. The anterior edge of the fascia is then sutured posteriorly to overlap the posterior edge.

Jones eliminated the snapping by attaching the overdeveloped gluteus maximus tendon to the length of the greater trochanter

Mayer incises the fascial band transversely below the level of the greater trochanter and, to prevent reunion of the edges, sutures them to the bone one-half inch apart.

As suggested by Pruitt, simple division of the tight fascial band with early mobilization of the hip might possibly be sufficient

After Treatment.—Exercises should be instituted as soon as the wound has healed.

SNAPPING SHOULDER

Snapping shoulder is a less definite entity than snapping hip The etiology varies, and may not be determined except by an exploratory operation.

Kappis states that snapping shoulder usually is caused by a contracted bundle of the deltoid muscle fibers. In other cases, catching of the tuberosity between the short tendon of the biceps and the coracobrachialis muscle may be responsible Of thirteen snapping shoulders, the lesion was anterior in ten, posterior in two, and in one both anterior and posterior

Bristow reports a case in which abduction of the arm produced a snapping of the shoulder Considerable pain and disability ensued for a period of twenty four hours. At operation, the pathologic process was directly apparent muscle fibers which originated from the outer side of the short head of the biceps passed downward and outward toward the long head and on abduction and rotation of the arm, rode over the lesser tuberosity Removal of that portion of the muscle which came in contact with the lesser tuberosity, together with a strip of the tendon of the short head to which it was attached resulted in complete relief of symptoms. Verrall described a somewhat similar condition.

Snapping shoulder may also be produced by displacement of the biceps brachii tendon from the bicipital groove (p 1255), or by a mechanical impediment associated with supraspinatus syndrome (p 1230)

BURSITIS

Bursae are sacs lined by endothelial membrane, usually located around joints or at some point where skin, tendon or muscle moves over a bony prominence. They may or may not communicate with the joint cavity Their function is to protect the more delicate structures from pressure. Anatomically and physiologically, bursae are similar to tendon sheaths and the synovial membranes of joints, and are subject to the same disturbances, i.e., (1) acute or chronic trauma, (2) acute or chronic infection, and (3) low grade affections, such as gout, syphilis, or tuberculosis. Some bursae, such as those over the patella and olecranon process, are normally present others, as those over bunions, osteochondromata, or kyphosis in tuberculous spines, are extrinsic or adventitious, being produced by repeated trauma or constant friction or pressure Kuhns and Buck, McDonald and Ghormley have shown that adventitious bursae do not have a true endothelial or synovial lining (Fig 887) Kuhns reports that the same pathologic changes may be found in adventitious bursae, such as infection, tumors, enlargements, and fibrosis, as are seen in normal bursae.

The treatment of bursitis, whether conservative or surgical, must be undertaken with due thought for both local and constitutional factors. In the majority of cases, conservative measures are adequate These consist of eradication of the constitutional causes, such as gout or syphilis, removal of

foci of infection elimination of local traumatic or irritating agents, or a change of occupation or posture. Other conservative measures, as hot wet packs, aspiration irrigation pressure bandages, and immobilization, are also effective.

At one time the injection of iodine was tried in subacute and chronic bursitis following trauma but, because of the excessive reaction and occasional necrosis, this treatment was abandoned. Kaplan and Ferguson, in 1937 suggested obliteration of the sac by sodium morrhuate following aspiration of the fluid Since sodium morrhuate has been uniformly successful in the treatment of sclerosing varicose veins, inducing a minimal reaction, perhaps this treatment is worthy of trial

Surgical procedures applicable to various affections of bursae consist of (1) drainage of acute suppurative bursitis (2) excision of bursae which are the sites of acute or chronic affection (3) aspiration In chronic lesions, the sac may be enormously thickened with villous formation and lobular masses, and consequently little likelihood of a return to normal it may be repeatedly distended by fluid after mild trauma or it may be occupied by or adjacent to calcareous deposits which do not recede following treatment for gout or are not relieved by aspiration and irrigation Frequently these calcareous deposits are not *in the bursae themselves. For example in a subacromial bursitis, the calcareous* mass usually lies in the tendon of the supraspinatus muscle rather than in the bursa.



Fig. 887—Photomicrograph show the difference in adventitious and true bursae adventitious bursae do not have a true endothelial or synovial lining. (From Buck, R. M. McDonald, J. R. and Ghormley R. K. Arch. Surg. 47: 344, 1943.)

Adventitious or extrinsic bursae which develop as a result of repeated trauma usually have a much thicker fibrous sac than is present in constant bursae, and are more subject to inflammatory changes. The surgical treatment of this type consists of removal of the causative agent such as excision of an osteochondroma, or correction of a club foot. The technics of these measures are described elsewhere at the time of operation the sacs usually are excised. Only the bursae which most often necessitate treatment by drainage or excision will be described

BURSITIS OF THE FOOT AND ANKLE

Constant and adventitious bursae may be demonstrated around the os calcis, internal and external malleoli (tailor s bursa) dorsum of the forefoot,

under the metatarsal arch, and over the prominence of a bunion These areas may or may not be painful or the sites of acute or chronic affections. The bursae are frequently associated with foot strain dorsal contractures of the toes paralysis or static deformities of the foot, spurs on the os calcis, and epiphysitis. The use of ill fitting shoes is a common causative factor The late Percy Roberts operated upon many painful areas in the sole of the foot which he considered the sites of bursitis, but in our experience surgery primarily for bursitis in this location is rarely warranted

Bursae which of themselves require surgical treatment most often are the retrocalcaneal bursa between the tendo achillis and the tuberosity of the os calcis, and the calcaneal bursa between the tendo achillis and the skin

Technic.—An incision three inches in length is made along the medial border of the tendo achillis. The deep fascia is divided and the bursa dissected out bluntly and if feasible in toto Frequently, an extensive reaction and adhesions between the bursa and the capsule forbid total resection and one must be content with removal of as much of the bursa and the adjacent fatty tissue as possible If the bursa extends proximally a sufficient amount of soft tissue must be left to prevent postoperative adhesions of the tendon. When the posterior superior edge of the os calcis is enlarged the process should be excised with an osteotome

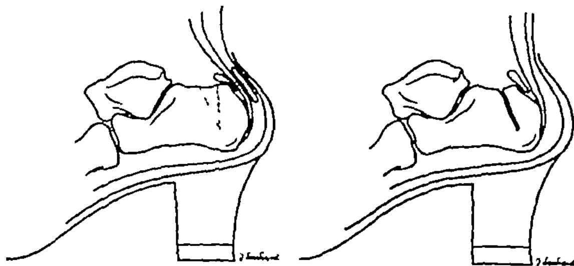


Fig 886.—Operation for relief of achillobursitis. (From Zadek, I : Am. J Surg 43: 542, 1939)

Calcaneal bursae may be exposed by incision over the fluctuant prominence. Removal is easily effected An adequate amount of subcutaneous fat should remain to preclude the development of adhesions.

After Treatment.—A short posterior night splint is applied for immobilization. Walking is allowed as soon as the acute symptoms have subsided and weight bearing is instituted after nine days the counter having first been removed from the shoe of the affected foot.

The operation described by Zadek for relief of achillobursitis is based upon the assumption that removal of the bony projection at the *top of the os calcis* is necessary in order to effect a cure. This operation is also advantageous in that the original smooth covering over the posterior aspect of the os calcis is undisturbed.

Technic (Zadek).—A longitudinal incision approximately 2½ inches in length is made along the lateral border of the tendo achillis. The incision ex

tends down to the level of the insertion of the tendo achillis into the os calcis. The bursa is found lying immediately beneath the skin and superficial to the tendon. The entire bursa is isolated and removed. By sharp dissection, the exposure is now developed down to the os calcis anterior to the tendo achillis. Should the edge of the os calcis sharply project at its posterior superior border this portion of the bone is removed with a small osteotome. Zadek feels that this alone is not sufficient to effect a cure and that the essential feature of the operation consists of removal of a wedge of bone from the os calcis at a point ½ to ¾ inch from its posterior border The base of the wedge is directed upward and is approximately ¼ inch wide. The apex of the wedge is placed approximately two-thirds the distance between the superior and inferior surfaces of the os calcis. After removal of the wedge, the posterior fragment of the os calcis is shifted forward by closing the gap to accomplish this, the posterior fragment is countersunk into the anterior portion of the os calcis by means of a mallet and bone set. Approximation of the bony fragments is maintained by interrupted catgut sutures.

After Treatment.—A cast is applied with the foot in moderate equinus. The patient is allowed to walk with crutches after approximately two weeks, and support is continued for five weeks.

We have not used this procedure. It appears to remove the underlying cause of the bursa and in severe cases, would probably be worth while it is more extensive however than the one described above.

BURSITIS OF THE KNEE

Prepatellar Bursitis

The prepatellar bursa is a common location for pyogenic infection, particularly in children. Drainage is readily accomplished. In the presence of an unusually large bursa, the swelling may be so pronounced that an erroneous diagnosis of pyogenic infection of the knee joint may be made One should guard against such an error if the knee joint is opened for this condition, a pyogenic arthritis will develop If a correct diagnosis is made and the bursa is properly drained, the knee joint will not be involved.

Technic.—The mass is approached through two lateral incisions, one on each side of the patella, the contents are evacuated, and the bursa is loosely packed with vaseline gauze.

After Treatment.—As cellulitis of some degree is always present, the extremity is immobilized in a posterior splint and appropriate antibiotic therapy is instituted. The packing is changed at least twice each week.

Frequently despite adequate drainage sinuses may persist on one or both sides of the joint. Since the bursa does not communicate with the joint, there is no danger of invasion of the knee At the time of the first observation the patient should be informed that complete excision of the bursa may be required if the process does not heal by the procedure described above.

When the walls of the bursa are thickened from chronic inflammation, resection of the entire bursa usually is carried out with little difficulty If the lesion is acute and only a serous effusion is present, this may not be possible, although a sufficient amount of the bursa may be excised to afford relief of symptoms.

Technic.—Through a longitudinal midline incision four inches in length, or through a transverse incision, the sac is separated from the skin anteriorly and from the patellar aponeurosis posteriorly and resected as thoroughly as possible.

After Treatment.—Compression bandages are applied, the knee is immobilized in a posterior splint, and wet dressings are continued for several days. After two weeks the splint is removed and walking permitted, the knee remaining encased in a heavy bandage Recovery usually is uneventful

Tibial Collateral Ligament Bursitis

Voshell and Brantigan have observed bursae between the parallel portion of the tibial collateral ligament and the true capsule of the knee joint, such bursae may be located in five different positions, and as many as three have been found beneath this ligament in one knee They have also reported cases of bursitis and of calcification of one or more of these bursae. They suggest that the calcification may be identical with Pellegrini-Steida disease In bursitis of this type excision of the bursa is indicated after aspiration and other conservative measures fail With proper care, the bursa may be completely removed without damage to the meniscus, the synovial membrane of the knee joint the medial collateral ligament or the vessels and nerves in this region

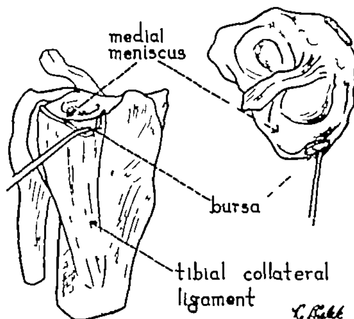


Fig. 339—Bursa located between parallel portion of tibial collateral ligament and medial meniscus. (From Brantigan, O C. and Voshell, A. F J Bone & Joint Surg 25: 121, 1943.)

Infrapatellar Bursitis

A small, deep subpatellar or infrapatellar bursa lies between the upper part of the tuberosity of the tibia and the ligamentum patellae and is separated from the synovial membrane of the knee joint by a pad of adipose tissue This bursa, when distended, causes a fluctuant swelling which obliterates the depression on each side of the ligamentum patellae while the center is depressed because of the resistance of the ligament. The treatment is similar to that of prepatellar bursitis.

BAKER'S CYST

(Semimembranosus Bursitis—Medial Gastrocnemius Bursitis)

Numerous bursae are located in the popliteal space between the hamstring tendons and the collateral ligaments or condyles of the tibia There is also a bursa between each head of the gastrocnemius muscle, and the posterior capsule of the knee joint and condyle of the femur Symptoms arise

most often in the bursa under the medial head of the gastrocnemius muscle and in the semimembranosus bursa, the latter is a double bursa which lies between the semimembranosus tendon and the inner condyle of the tibia, and between the semimembranosus tendon and the medial head of the gastrocnemius muscle.

In 1877, Baker described the cyst which has since borne his name, though this condition had been previously described by others. Meyerding and Van Demark state that Baker's cyst may be produced by either herniation of the synovial membrane through the posterior portion of the capsule of the knee joint or by escape of fluid through the normal connection of the bursae with the knee joint, i.e., either the semimembranosus bursa or the medial gastrocnemius bursa

The academic question of posterior herniation of synovium versus bursitis is of no importance so far as excision is concerned For surgical purposes, any cyst of the popliteal region may be a Baker's cyst. To facilitate description of the surgical anatomy the cysts shall be presumed to be enlarged medial gastrocnemius bursae or semimembranosus bursae.

As a rule, the diagnosis is not difficult though the condition must be distinguished from lipomas xanthomas, and other benign tumors, and from fibrosarcoma Vascular tumors and rarely an aneurysm may be confused with this condition Pyogenic abscesses are occasionally located in this area but should be easily differentiated The exact diagnosis may usually be made by transillumination of the cyst and by aspiration If the Baker's cyst is sufficiently large and presents symptoms, surgical treatment is the method of choice.

Medial Gastrocnemius Bursitis

When the medial gastrocnemius bursa is involved a palpable tumor may be located in the midline of the popliteal space or may extend beneath the head of the gastrocnemius muscle and appear between the medial head of that muscle and the semimembranosus tendon, simulating an enlargement of the semimembranosus bursa. If presented in the midline of the popliteal space, excision is carried out as described below

Technic (Meyerding and Van Demark)—An oblique incision is made directly over the tumor mass. After division of the deep fascia, the hernial sac is exposed and by blunt dissection, is isolated down to its attachment to the posterior aspect of the capsule of the knee joint. In some cases, relaxation of the muscles and tendons on each side of the cyst by flexion of the knee joint will facilitate the exposure The neck of the cyst is then clamped at its attachment to the capsule of the joint and is divided, sufficient length for inversion of the pedicle being allowed to remain Meyerding and Van Demark prefer permanent suture material for inversion of the pedicle. They also state that, at times, the pedicle may be ligated in other instances, the pedicle is widely excised and the capsule is left open They feel however that the latter procedure may predispose recurrence

After Treatment.—The knee is immobilized in extension with a posterior splint. Quadriceps exercises are begun on the second day following the operation. The patient is allowed up after the first week and is permitted to use crutches after approximately ten days. The skin sutures are not removed until the fourteenth day at this time, the splint is discarded

Semimembranosus Bursitis

The cyst presents on the medial aspect of the popliteal space on either the medial or lateral side of the semimembranosus tendon usually the latter

Technic.—A three inch slightly oblique or curved longitudinal incision is made over the medial aspect of the popliteal space It is a common error to place this incision too far proximally On incision of the deep fascia, the exact location and plane of dissection is usually evident *The interval between the semimembranosus and medial head of the gastrocnemius is developed separating the cyst wall from these structures.* There are no important nerves or vessels in this plane of cleavage the latter being protected

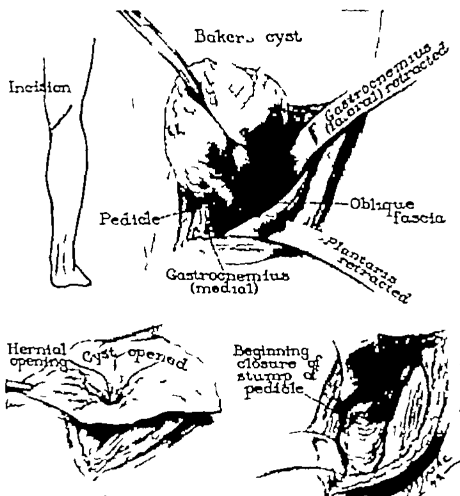


Fig 890—Removal of Baker's cyst. Insert shows line of skin incision. After exposure of pedicle of cyst, base is ligated and inverted. (From Meyerding H. W., and Van Demark, G E. J A. M. A. 122 858, 1943.)

by the medial head of the gastrocnemius. As dissection proceeds, it will be increasingly difficult to separate the cyst wall from adjacent structures. In the depths of the wound it is usually firmly adherent, requiring sharp dissection that includes some of the fibrous portions of the semimembranosus or the gastrocnemius otherwise the wall of the cyst will be ruptured making it difficult to define the limits of the cyst and determine the presence of a stalk or pedicle The base of the cyst frequently manifests no evident channel into the joint, but is intimately bound up with the capsule and synovium. A broad

most often in the bursa under the medial head of the gastrocnemius muscle and in the semimembranosus bursa, the latter is a double bursa which lies between the semimembranosus tendon and the inner condyle of the tibia, and *between the semimembranosus tendon and the medial head of the gastrocnemius muscle.*

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As a rule the diagnosis is not difficult though the condition must be distinguished from lipomas, xanthomas and other benign tumors, and from fibrosarcoma. Vascular tumors and rarely an aneurysm may be confused with this condition. Pyogenic abscesses are occasionally located in this area but should be easily differentiated. The exact diagnosis may usually be made by transillumination of the cyst and by aspiration. *If the Baker's cyst is sufficiently* large and presents symptoms, surgical treatment is the method of choice.

Medial Gastrocnemius Bursitis

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After Treatment.—The knee is immobilized in extension with a posterior splint. Quadriceps exercises are begun on the second day following the operation. The patient is allowed up after the first week and is permitted to use crutches after approximately ten days. The skin sutures are not removed until the fourteenth day at this time the splint is discarded.

Semimembranosus Bursitis

The cyst presents on the medial aspect of the popliteal space on either the medial or lateral side of the semimembranosus tendon, usually, the latter

Technic.—A three-inch slightly oblique or curved longitudinal incision is made over the medial aspect of the popliteal space. It is a common error to place this incision too far proximally On incision of the deep fascia the exact location and plane of dissection is usually evident The interval between the semimembranosus and medial head of the gastrocnemius is developed separating the cyst wall from these structures. There are no important nerves or vessels in this plane of cleavage the latter being protected

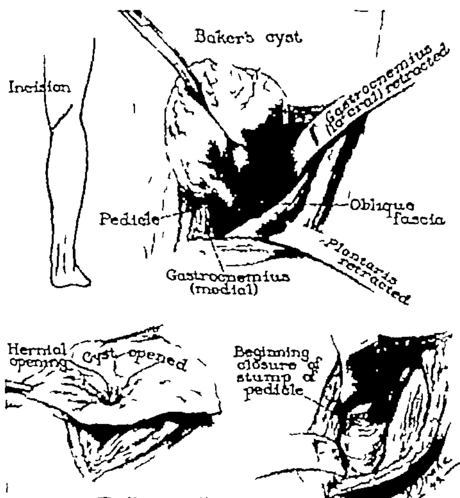


Fig 690.—Removal of Baker's cyst. Insert shows line of skin incision. After exposure of pedicle of cyst, base is ligated and inverted. (From Meyerding H. W and Van Demark, G E. J A. M. A. 121: 858, 1943.)

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excision of this area precludes the possibility of recurrence. In this process, the attachment of the gastrocnemius may be partially or wholly incised to facilitate exposure.

The technic for cysts on the medial side of the semimembranosus tendon follows essentially the same pattern

After Treatment.—See above.

BURSITIS OF THE HIP

Bursae Associated With the Gluteus Maximus Muscle

Many bursae have been described in this region Gray s Anatomy however lists three principal bursae. One usually large and multilocular separates the deep surface of the gluteus maximus muscle from the greater trochanter and the short rotator muscles. A second, if present, is situated over the tuberosity of the ischium (see below) A third is located between insertion of the tendon of the gluteus maximus muscle and the vastus lateralis muscle. Any one of these may be involved in a pathologic process, though the one most encountered is the first, i e., the large bursa lying between the gluteus maximus muscle and the greater trochanter

Subgluteal Bursitis

Cooperman has called attention to acute hematogenous bursitis involving this and other bursae. At the clinic, we have encountered acute infection of this bursa with the formation of purulent material on several occasions. As pointed out by Cooperman distinction between this condition and pyogenic arthritis of the hip joint is important otherwise, the hip may be needlessly opened and a normal joint subjected to the danger of a purulent infection Any deep-seated pain over the posterior aspect of the hip associated with systemic signs of infection calls for a careful search for an infected bursa Usually the diagnosis may be made by aspiration Because of the deep-seated location of the bursa, however the formation of purulent material is usually rather abundant before an exact diagnosis can be made.

Technic of Drainage—A modification of Osborne s approach (p 149) is employed. The upper portion of the incision is connected with a vertical incision which extends downward along the posterior aspect of the femur over the area of insertion of the gluteus maximus tendon The fibers of the gluteus maximus are separated by blunt dissection along the upper limb of the incision and any blood vessels encountered in the muscle or on its anterior aspect are ligated. The insertion of the gluteus maximus into the upper portion of the lenea aspera is divided, and the triangular flap so formed is retracted downward and medially exposing the bursa lying between the gluteus maximus and the posterior aspect of the trochanter and the short rotator muscles of the hip This will adequately drain the bursa. The wound is lightly packed with petrolatum gauze and a dressing applied. Immobilization of the hip in a spica cast may or may not be necessary depending upon the severity of the condition. The drainage suggested above is accomplished without jeopardizing the hip joint.

Peritrochanteric Bursitis

Tuberculosis of the peritrochanteric bursae is not uncommon. In the absence of an obvious acute infectious process, this diagnosis should be considered, the bursa aspirated and the material should be cultured for tuberculosis,

or a guinea pig inoculation done In the presence of a tuberculous process of the bursa without draining sinuses, complete excision of the bursa followed by closure of the wound usually affords good results In such cases, antibiotic therapy should be given both before and after the operation, as a precaution against secondary infection since troublesome draining sinuses are associated with the development of a mixed infection As reported by Farr and others a tuberculous infection of the bursa may not extend to the bone though the bursa may be involved from a small tuberculous focus originating in the trochanteric region of the bone

Technic of Drainage —The bursa between the vastus lateralis and the tendon of insertion of the gluteus maximus may be drained through a longitudinal incision over the posterolateral aspect of the greater trochanter The approach extends through the deep fascia The fascia lata is divided posterior to and below the muscle fibers of the tensor fascia femoris muscle and the space is opened between the vastus lateralis laterally and anteriorly, and the insertion of the gluteus maximus tendon into the upper portion of the linea aspera posteriorly and medially Any purulent material present in the bursa is adequately drained through this approach The wound is lightly packed with petrolatum gauze

Trochanteric Bursitis With Calcification

DeLorimier Schein and Lehmann and a number of other authors have called attention to the frequent development of a trochanteric bursitis with calcification Schein and Lehmann particularly pointed out the analogy between acute bursitis of this type and in the shoulder The calcification in both is located in a tendon adjacent to a bursa at the proximal end of the limb The two conditions are similar also in that any treatment which produces hyperemia and an increase in the vascularity about the process promotes absorption of the deposit of calcium and subsidence of the symptoms. We have observed several patients with trochanteric bursitis with calcification. These lesions usually respond to treatment more readily than those about the shoulder joint Conservative measures, such as applications of heat, infiltrations with Novocain or at most, multiple perforations with a needle under local anesthesia have sufficed. In our experience none of the cases of calcification about the hip have been sufficiently severe to require surgery

Ischiogluteal Bursitis (Weaver s Bottom)

The ischiogluteal bursa lies between the tuberosity of the ischium and the gluteus maximus muscle. Individuals whose occupation necessitates a sitting posture are chiefly affected, as the inflammation of the bursa usually is induced by constant irritation from this position. Conservative treatment generally suffices, an acute suppurative process may develop however, requiring drainage.

Technic.—An incision three inches in length is made over the prominence of the tuberosity in line with the lower fibers of the gluteus maximus muscle, and this structure is divided by blunt dissection to expose the bursa. The sciatic nerve lies just lateral to the tuberosity of the ischium. In an acute suppurative process the bursa is incised and packed with vaseline gauze. If the pathologic process is chronic, the bursa may be removed.

Iliopectineal Bursitis

The iliopectineal bursa lies between the iliopsoas muscle and the pelvis and often communicates with the hip joint. Posteriorly and superiorly the sac comes in contact with the iliopectineal eminence, and below with the capsule of the joint.

Technic.—The incision begins at the anterior superior spine and extends along the medial border of the sartorius muscle a distance of five inches. The superficial iliac circumflex vessels are ligated and divided One inch distal to the anterior superior spine, the tendinous origin of the sartorius muscle is severed transversely and retracted laterally the femoral nerve is retracted medially The rectus femoris muscle is divided just below the anterior inferior spine and retracted laterally with the sartorius muscle, bringing into view the iliopsoas muscle To expose the bursa beneath this muscle, the thigh is partially flexed and rotated externally and the iliopsoas muscle is retracted medially To provide a more complete exposure the iliopsoas tendon may be incised near its insertion, or the incision may be extended proximally along the crest of the ilium and the iliacus muscle dissected subperiosteally from the inner table of the ilium.

In acute suppurative bursitis, the wall of the bursa is incised and a drain inserted. If the bursa communicates with the joint cavity and both are involved in a suppurative process, the hip joint is drained through an appropriate incision.

BURSITIS OF THE SPINE

Adventitious bursae are frequently observed over the prominence of a kyphos or bone graft of the spine The osseous eminence and bursa are excised at the same operation

Acutely tender bursae may also be associated with elongation of a single spinous process (p 877) calcareous deposits in the supraspinous ligaments (p 878) or kissing spines (p 877)

Technic.—A curved longitudinal incision three or four inches in length is made on either side of the protuberance. The bursa, which lies between the skin and the bone, is often three inches in length and two inches in width The walls are quite thick, permitting enucleation without difficulty To prevent recurrence, the prominent spinous process or protruding portion of the graft is removed with rongeurs.

Occasionally calcareous deposits are found in the supraspinous ligaments or beneath the bursa In this event, removal of the deposit, and excision of the surrounding ligament and tip of the spinous process is the proper treatment.

BURSITIS OF THE SHOULDER

Subdeltoid or Subacromial Bursitis

The subacromial bursa more often than any other is involved in an inflammatory process. The bursa is so intimately connected with the musculotendinous cuff of the shoulder that lesions of either secondarily affect the other Primary lesions being less common treatment of lesions of this bursa are described under Supraspinatus Syndrome (p 1230)

Subscapularis Bursitis

This is an inflammation of a small bursa which lies on the anterior medial surface of the humeral head, between the tendon of the subscapularis muscle

and the capsule of the shoulder joint and communicates directly with the joint As a rule the inflammation of the sac is associated with disease of the joint proper, and is important only as a point of secondary pocketing in purulent affections of the joint

BURSITIS OF THE ELBOW

Olecranon Bursitis

There are two olecranon bursae of clinical importance One separates the tendon of the triceps muscle from the posterior ligament of the elbow and the olecranon The second which is much more often involved in a pathologic process, lies between the attachment of the triceps muscle to the olecranon process and the skin Because of its subcutaneous location either drainage or excision may be readily carried out through a longitudinal or transverse incision

Radiohumeral Bursitis

See "Tennis Elbow"

ELEPHANTIASIS

In temperate regions, elephantiasis incident to filaria is encountered only in patients who have contracted the disease while living in the tropics. Homans states that the sporadic or idiopathic form, known as elephantiasis nostra is more common than Milroy s disease (familial form) The two are similar both pathologically and clinically

In mild cases, the swelling may be controlled by conservative measures, such as bandaging, the use of elastic stockings, and elevation of the extremity at night. In severe cases, however the leg becomes cumbersome and walking is difficult, and sooner or later recurrent patches of an erysipeloid type of infection appear Abscess formation, however is not associated with this condition

Kondoleon s procedure is no longer employed. The results were poor and the theory *upon which it was based (drainage of the superficial lymphatics* into the deep lymphatics) is not sound in that the muscles probably have no lymphatics.

Both Homans and Macey state that surgical treatment should be limited to the tissue below the knee after suitable operative therapy, the swelling of the thigh usually improves and the remaining enlargement may be controlled by conservative measures. In Homans' operation, the skin covering the affected leg is used as a graft this is an advantage provided the skin is relatively normal. In Macey s operation, skin which has been damaged by infection is removed Homans is of the opinion that, if the elephantiasis is primarily of infectious origin the advisability of plastic surgery is questionable

Homans operation consists of four stages (Fig 891) The second stage may be carried out a week or more after the first stage i.e. as soon as the wound has healed and the grafts have taken At least two months or more should elapse between the first and second stages and the third and fourth stages as the grafts must be allowed to take well before the last two stages are undertaken. The operation is performed under a tourniquet.

Technic (Homans) —At the first operation long flaps are outlined on the anteromedial aspect of the leg dissection being carried through the deep fascia (aponeurosis) The thick flaps are reflected from both sides of the incision

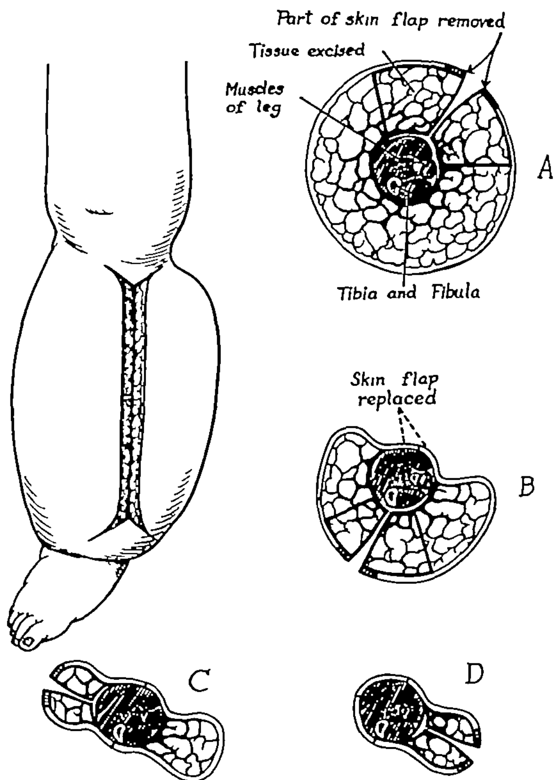


Fig. 891.—Homan's technic for elephantiasis is carried out in four stages, as represented by *A*, *B*, *C* and *D*. Shaded area represents amount of tissue to be excised at each successive stage. Subsequent development of this operation included a plastic procedure upon the foot, which is not illustrated. (From Homans, J.: New England J. Med. 215: 1099, 1936.)

exposing at least a quarter of the circumference of the leg The flaps are next prepared by excision of the lymph-soaked tissue. The tourniquet is removed and bleeding controlled The denuded area is then covered with the skin flaps, thus abolishing the dead space. After one is assured that the circulation of the flap is adequate, the excess skin is removed The long broad hollow in the leg is filled with gauze and a pressure bandage applied, as is customary in ordinary skin grafting This pressure dressing holds the graft in position and prevents elevation of the graft by the flow of fluid from the adjacent tissues.

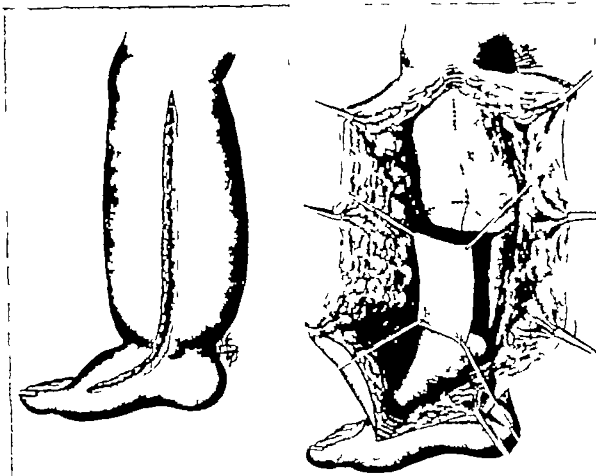


Fig 892.—Macey technic for elephantiasis. A Schematic drawing of skin incision. B Subcutaneous dissection of diseased tissue application of split skin grafts covering fasciae, muscle sheaths, and peritendinous structures. (From Macey H. B. J Bone & Joint Surg. 30-A: 339, 1948.)

After healing of the wound is complete and the graft has taken, it will not be elevated by the excess fluid in the remaining subcutaneous tissue of the leg At this time a similar procedure (the second stage) is performed on the posterolateral aspect of the leg At this operation, one should take care to preserve the sural nerve, as a part of the nerve supply in the heel should be left intact. After the wound has healed following the second operation the patient is allowed to go home for two months or longer During this period, adequate pressure dressings are maintained on the extremity and the foot is kept elevated as much as possible.

In some cases a similar procedure may be necessary on the foot. In this event, the operation is performed on a smaller scale The first incision is placed

so as not to be continuous with those in the leg Usually the operation may be completed in one or two stages.

After the skin grafts from the first two stages have acquired a sound blood supply from the adjacent deep structure the remaining pathologic tissue is removed in two stages in a manner similar to that described for the first and second stages

Macey has found that the pathologic process is confined entirely to the skin and subcutaneous tissue and that the underlying structures are apparently normal for this reason his procedure is designed to eradicate all the diseased tissue. He states that it should be confined to the tissues below the knee and, if possible, below the elbow

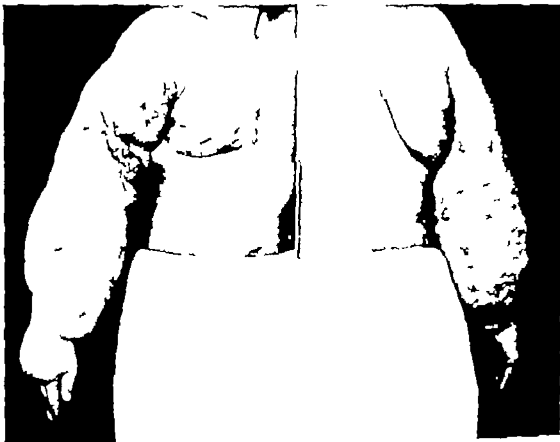


Fig. 893.—Extensive lymphedema of right arm. (From Macey H. B. J Bone & Joint Surg. 30-A: 339, 1948.)

In performing this operation the skin grafts may be taken from the affected thigh, provided the skin is normal and there are no contraindications, though grafts from other portions of the body are usually employed. Cellulitis and lymphangitis in the extremities have not recurred following this procedure, nor has recurrent cellulitis or lymphangitis been observed as the result of recurrent pyogenic infections incident to a flare-up in a previously sensitized tissue. Macey has performed the operation on seven patients, with excellent functional results.

Before the operation, the extremity is elevated and drained of as much of the lymphadematous fluid as possible. If cellulitis is present, conservative measures are employed until the infection subsides an antibiotic should be administered both before and after operation

Technic (Macey).—The operation is performed in two stages, the first being on either the inner or outer aspect of the leg (Fig. 892). The incision is made down to the deep fascia from the base of the toes to the knee curving over the malleolus. At the malleolus dissection is carried distally and posteriorly to a point corresponding approximately to the upper margin of a low-quarter shoe. A thin layer of peritendinous and perifascial tissue is left over the fascia and tendon as a bed for the skin graft. To prevent extrusion of muscle, the deep fascia is not excised. The dissection comprises half the circumference of the extremity. A sufficient number of split skin grafts are taken to cover the defect; these are removed from the thigh or other suitable donor sites. The grafts are sutured in position over the fascia beneath the elevated subcutaneous tissue. Multiple puncture holes are placed in the skin grafts as the recipient area is avascular and Macey believes that possibly some nourishment to the graft may be furnished by the overlying subcutaneous tissue. No drains are inserted.



Fig. 894.—Same as Fig. 893. Appearance of right arm seven years after excision of lymphedematous tissue and skin grafting. (From Macey, H. B.: J. Bone & Joint Surg. 30-A 339, 1948.)

After Treatment.—Skin and subcutaneous tissue are closed over the grafts and a compression dressing is applied. On the seventh to ninth postoperative days, the pathologic tissue lying over the grafted area is excised and the subcutaneous tissue adjacent to the margin of the graft is removed by undermining. This permits a somewhat flattened closure of the margins of the skin graft to the adjacent skin. The grafted area is supported by elastic bandages for at least ten to twelve weeks following the operation. Macey states that in no case have these buried grafts failed to take.



Fig 806.—Appearance of extensive lymphedema of right lower extremity before surgery (From Macey H. B. J Bone & Joint Surg. 30-A: 339 1948.)

The second stage is not attempted until after a period of four months have elapsed At this stage a similar operation is performed the remaining portion of the leg being covered with skin grafts followed after seven to nine days by excision of the overlying pathologic tissue

After the operations, the grafts may be maintained in good condition by daily use of softening hand cream Of Macey's seven operations, six were performed on the lower extremity and one on the upper extremity The results were uniformly satisfactory



Fig 896.—Same as Fig 895. Appearance of right lower extremity six years after excision of lymphedematous tissue and skin grafting on inner aspect of leg and eighteen months after excision of lymphedematous tissue and skin grafting on outer aspect of leg (From Macey H. R. J Bone & Joint Surg. 30-A: 339 1948.)

References

Abbott, A. C: Dupuytren s Contracture Review of Literature and Report of New Technique in Surgical Treatment, Canad. M. A J 20 250 1929

Baker W M.: On the Formation of Synovial Cysts in the Leg in Connection with Disease in the Knee Joint, St. Barth. Hosp Rep 13 245 1877

—: The Formation of Abnormal Synovial Cysts in Connection with the Joints, St. Barth. Hosp Rep. 21: 177 1885.

Baker W M The Formation of Synovial Cysts in the Leg in Connection With Disease of the Knee Joint, St Bartholomew Hosp. Reports 13 245 1877

Binnie, J F: Snapping Hip, Ann. Surg 58 59 1913

Brantigan O C., and Voshell A. F The Tibial Collateral Ligament Its Function, Its Bursae and Its Relation to the Medial Meniscus J Bone & Joint Surg 25 121 1943

Bristow W R. A Case of Snapping Shoulder J Bone & Joint Surg 6: 53, 1924.
Buck, R. M McDonald J R., and Ghormley R K. Adventitious Bursas, Arch. Surg. 47 344 1943.
Bunnell S. Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.
Carrell, W B. Discussion of paper by Parsons Texas State J Med. 26 362, 1930.
Codman E. A.: On Stiff and Painful Shoulders, Boston M & S. J 154 613 1906.
— The Shoulder Boston, Mass., 1934.
Cooperman, M B Acute Hematogenou Bursitis, Ann Surg. 108 1094 1938
Cravener E. K.: Hernia of the Knee Joint (Baker s Cyst) J Bone & Joint Surg. 14 186, 1932.
DeLorimier, A. A. Roentgen Therapy in Acute Periarthriti Am. J Roentgenol. 38 178 193
Davis, J S., and Finesilver E. M Dupuytren s Contraction Arch Surg. 24 933 1932.
Dickinson, A. M. Bilateral Snapping Hip Am. J Surg. 6 07, 1929
Farr J Tuberculosi of Bursa in the Region of the Hip Joint Canad. M. A. J 50 60 1944.
Finder, J G Iliopectineal Bursitis, Arch. Surg. 36 510 1938.
Ghormley R. K., and Overton L. M. The Surgical Treatment of Severe Forms of Lymphedema (Elephantia is) of the Extremities Surg Gynec. Obst. 61 83, 1935.
Homans, John The Treatment of Elephantiasis of the Legs, New England J Med. 215 1099 1936.
Jones, F Wood The Anatomy of Snapping Hip J Orthop. Surg. 2 1 1920.
Kanavel, A. B., Koch, S. L., and Mason M L. Dupuytren s Contraction, Surg. Gynec. Obst. 48 145 1929
Kaplan, L., and Ferguson L. K. Bursitis Am. J Surg 37 455, 1937
Kappis Snapping Shoulder, Twenty First Report of Progress in Orthopedic Surgery p. 37 (Abst. from Arch f orthop. Chir 20 535 1922.)
Koch S. L. Dupuytren s Contraction, J A. M. A. 100 878 1933.
Kuhns, J G Adventitiou Bursa Arch. Surg 46 687 1943.
LeCocq Edward: Peritrochanteric Bursitis, J Bone & Joint Surg. 13 872, 1931.
Leemans Extra Articular and Intra Articular Snapping Hip, Internat. Abstr Surg. 52. 508 1931 (Abst from Arch. franco-belges de chir 32 302, 1929 30.)
Livingston W K.: Clinical Aspects of Visceral Neurology Springfield, Ill., 1935 Charles C. Thoma
Luck, J Vernon: Personal communication, 1948
Macey H. R.: A Surgical Procedure for Lymphoedema of the Extremities, J Bone & Joint Surg 30-A 339 1948.
Mayer Leo: Snapping Hip Surg Gynec. Obst. 29 425 1919
Meyerding H. W., Black, J R., and Broders A C.: The Etiology and Pathology of Dupuytren s Contracture Surg Gynec Obst. 72 582, 1941
Meyerding H. W., and Van Demark, R E.: Posterior Hernia of the Knee (Baker s Cyst, Popliteal Cyst Semimembranosu Bursitis Medial Ga trocnemius Bursitis and Popliteal Bursiti) J A M A. 122 858 1943.
Milroy W F Chronic Hereditary Edema: Milroy s Disease J A. M. A. 91 1172, 1928.
Moreira, F E. G Snapping Hip Abst., J Bone & Joint Surg 22 506, 1940.
Patterson, R. L., Jr., and Darrach, William Treatment of Acute Bursitis by Needle Irrigation J Bone & Joint Surg 19 993 1937
Parsons, E. B. The Snapping Hip, Texas State J Med. 26 361 1930
Pruitt, M. C. Snapping Hip J M. A. Georgia 10 25, 1920
Roberts P W: Fifty Cases of Bursitis of the Foot, J Bone & Joint Surg. 11: 338 1929.
Rogers, Mark H. A Study of One Hundred Cases of Subdeltoid Bursitis, J Bone & Joint Surg. 16 145, 1934.
Schein A. J., and Lehmann, O. Acute Trochanteric Bursitis With Calcification, Surgery 9 771 1941
Voshell, A. F., and Brantigan O C Bursiti in the Region of the Tibial Collateral Ligament J Bone & Joint Surg 26 93 1944
Wilson P D., Eyre-Brook, A. L., and Franc s, J D A Clinical and Anatomical Study of the Semimembranosus Bursa in Relation to Popliteal Cyst, J Bone & Joint Surg 20 963, 1938
Zadek, I. An Operation for the Cure of Achillobursitis, Am. J Surg. 43 542, 1939

CHAPTER XXII

ANTERIOR POLIOMYELITIS

The treatment of poliomyelitis by surgical measures should not as a rule, be undertaken until the residual stage of the disease has been well established and improvement in muscle power can no longer be expected from conservative treatment This stage is seldom reached until the lapse of two years following the onset of the paralysis. Prior to that time, or during the period of resolution deformity may arise if treatment is neglected, in this event, surgery may occasionally be necessary, not only to place the member in a satisfactory position for future use but to relieve the overstretching of paralyzed or weakened muscles, which is not conducive to a return of power

Operative measures for the residual stage of poliomyelitis are designed to (1) correct deformity including discrepancies of leg length (2) re-establish muscle power and (3) stabilize relaxed or flail joints, all of which are directed toward restoration of the member to the maximum degree of function

Prior to operation the surgeon must anticipate the possible effect of a contemplated procedure upon the function of the affected extremity as a whole and, in some cases, upon the spine as well. For example a patient with paralysis of the quadriceps muscle and fixed equinus deformity may walk well, the contracted calf muscles stabilizing the knee through their origin on the condyles of the femur If the tendo achillis is made too long in correcting the equinus deformity the foot and knee may be unstable, rendering the extremity less efficient and the patient more disabled than before correction was attempted Further, when paralysis is so extensive as to necessitate the permanent use of a long brace other than correction of deformity little is accomplished by stabilization of the foot. If the maximum degree of usefulness is to be restored operations must be planned along correct mechanical and dynamic lines, with due consideration for the existing status of the extremity

CORRECTION OF DEFORMITY

Deformity associated with infantile paralysis may be the result of muscle imbalance unrelieved muscle spasm gravity or habitually faulty posture Frequently the patient is not observed until months or years after the onset of the paralysis and multiple fixed deformities have developed. In such cases, the patient s chief disability may arise from the fixed deformities themselves, and several operations may be required to place the affected extremity in a functional position If the deformities are of relatively recent origin conservative measures, as special apparatus, traction or forcible correction may suffice.

Operations for correction of contracted soft structures consist of tenotomies, lengthening of tendons, fasciotomies, and capsulotomies. In deformities of long standing the normal contour of the bones may be altered, necessitating osteotomies and bone plastic procedures. These are described in the chapter on Ankylosis and Deformity

RE-ESTABLISHMENT OF MUSCLE POWER (TENDON TRANSFERENCE)

Tendon transference is often incorrectly called tendon transplantation. The latter embodies excision of all or a part of a tendon as a free or unattached transplant. The procedure under discussion is the transference of a tendinous insertion from its normal attachment to another location, to serve as a substitute for a paralyzed muscle

Abroad, Nicoladoni Velpeau, Helferich Salvia, Lange, Vulpius, and Codivilla and in this country Parrish Goldthwait, Mayer and Milliken, were responsible for making tendon transference practicable. Hundreds of variations of the pioneer procedures have since been devised. Obviously a description of all these operations would be impossible only those which have proved most efficient will be given. No attempt, moreover, will be made to establish priority

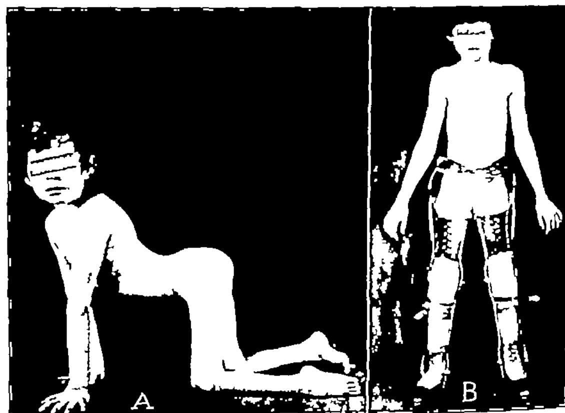


Fig. 337—*A*, Quadruped with fixed flexion contracture of knees and hips, and equinus deformity of ankles. *B* Deformities corrected by transference of crests of ilia, posterior capsulotomies of the knees and lengthening of the tendo achillis bilaterally

Careful judgment must be exercised in the selection of a tendon for transference. First, the respective muscle must have sufficient power to replace to a satisfactory degree the function of the paralyzed muscle. If the muscle of the tendon to be transferred is weakened by paralysis or its normal power is inadequate, the expected action may not be possible or the muscle may function for a short time and thereafter because of overstretching may *lose its* power

Second, in order to perform the function of the paralyzed muscle efficiently, the free end of the transferred tendon should be attached to the bone as near

His second postulate, namely proper evaluation of the muscle for transposition, both as to power and as to its physiologic adaptability is well known and has already been discussed.

STABILIZATION OF RELAXED OR FLAIL JOINTS

Relaxed or flail joints are stabilized by complete or partial restriction of the normal range of motion or elimination of abnormal or undesirable motion *Operations on the bones are of two types* bone plastic procedures (arthrorises) and arthrodeses. In bone plastic procedures, as a rule, some degree of serviceable motion is preserved in the affected joint In arthrodesis, the joint surfaces are remodeled to permit fusion in a satisfactory position for future function

Stabilization has also been attempted by tenodesis, ligament fixation, or the reconstruction of artificial check ligaments from fascia lata or silk. With a few exceptions, these procedures have been discarded for two reasons first, even though stabilization with soft tissue or artificial ligaments is successful, if these materials do not stretch with growth a deformity in the opposite direction may eventually be created second, artificial check ligaments fashioned from tendons or fascia lata may be satisfactory for a few months or years, and then, because of constant strain and tension may overstretch and lose their function to a commensurate degree Stabilization by operations on the osseous structures is much more permanent and efficient as a rule, than by the operations on the soft tissues.

Although a properly reconstructed brace may afford relatively satisfactory function unquestionably the use of a brace is less desirable than a reconstruction operation which will not only obviate the need for external support, but also improve function.

FOOT AND ANKLE

The foot, being the most dependent part of the body is of course subjected to greater strain and is therefore particularly susceptible to deformity following paralysis. The deformities observed are equinus, varus, valgus, calcaneus, cavus, equinovarus, calcaneovalgus, equinovalgus, drop foot, and flail foot. In the early stage of paralysis, these deformities are not fixed and may be evident only upon contracture of unopposed muscles or on weight bearing Subsequently as a result of muscle imbalance contracture of the soft structures, and abnormal contour of the bones, a permanent deformity is established.

CORRECTION OF DEFORMITY

In this section will be described operations for contracture of the toes and cavus or clawfoot deformity Operations for correction of deformity which entail resection or arthrodesis of the tarsus are described in the section on Stabilization of the Foot and Ankle.

Clawtoes

Clawtoe is characterized by hyperextension of the metatarsophalangeal joint, flexion of the proximal interphalangeal joint, and flexion or extension of the distal phalangeal joint, from overaction of the extensor tendons, or weakness or paralysis of the flexor or intrinsic muscles of the foot. All the toes are, as a rule, affected the contracture of the first being most severe. This

is explained by the fact that the action of the extensor hallucis longus muscle is relatively stronger than that of the extensor digitorum on the second, third, fourth, or fifth toes. The deformity may not be apparent when the extensor muscles are relaxed, as in standing but only upon attempts to dorsiflex the foot and ankle In walking, the flexed proximal interphalangeal joints are constantly irritated from rubbing against the top of the shoe, and the heads of the metatarsal bones are depressed and prominent on the plantar surface of the foot causing painful calluses at these points. During a period of months or years, the soft tissues gradually contract to conform to the deformity, preventing resumption of the normal position of the toes.

When clawtoes are associated with a cavus or clawfoot deformity, correction of the cavus should be undertaken first, as the contracture of the toes may be relaxed when the longitudinal arch is restored to its normal height and the forefoot is elevated (pp 1295, 1331)

Other than for deformity of the great toe, correction of a single toe is seldom necessary in poliomyelitis. As a rule, all five of the toes are contracted sufficiently to warrant surgery The contracture of the second, third fourth and fifth toes is corrected by lengthening of the extensor tendons and dorsal capsulotomy of the metatarsophalangeal joints. The great toe may be corrected by the procedure of Dickson and Dively, Jones, Wagner or Forrester Brown, described further

Technic.—The skin between the second and third metatarsal bones is incised for one and one half to two inches, beginning distally at a level with the metatarsophalangeal joint. The edge of the incision is retracted medially and the long extensor tendon to the second toe is severed by a long oblique or Z-plastic incision. The dorsal capsule of the metatarsophalangeal joint is exposed and completely resected The joint is then forcibly flexed into an overcorrected position of plantar flexion By retraction of the incision laterally the third toe may be corrected in the same manner

A second incision of equal length is now made between the fourth and fifth metatarsal bones, the extensor tendons to these toes are lengthened and the dorsal capsules of the fourth and fifth metatarsophalangeal joints resected. No attempt is made to suture the tendons, since they are fairly well approximated and will unite and function adequately

If the above procedure is not successful, resection of the heads of the metatarsal bones will afford the best anatomic correction. The technic embodies the principles of the Hoffman operation (p 841) in which the toes are shortened by resection of the heads of the metatarsal bones. Following dorsal capsulotomy and lengthening of the extensor tendons, the head of the second metatarsal bone is divested of its soft tissue attachments, grasped with a forceps, elevated, and severed. This is repeated for the third, fourth and fifth metatarsal bones. The flexion contracture of the interphalangeal joint is corrected by subcutaneous tenotomy of the flexor tendons, followed by forcible extension of the joint. If this is not adequate, a transverse incision is made across the dorsum of the interphalangeal joints, and the base of the middle phalanx and head of the proximal phalanx are resected (See Jones technic for hammertoes, p 1294)

Theoretically, removal of the head of the metatarsal bones destroys an important weight bearing surface, but practically, the results have been satisfactory

Clawtoe Deformity of the Great Toe

Clawtoe deformity of the great toe is a common finding in paralytic feet. Operative procedures not only correct the deformity but utilize the power of the extensor hallucis longus tendon to aid in dorsiflexion of the foot.

Technic (Dickson and Diveley)—The flexor hallucis longus tendon is exposed by an incision along the medial border of the head of the first metatarsal bone. The tendon *is grasped with forceps just proximal to the head and* placed under tension, acutely flexing the metatarsophalangeal and interphalangeal joints. A second incision is made along the extensor hallucis *longus tendon from the base of the first metatarsal bone to the first phalanx*, and the tendon is isolated and incised just proximal to the interphalangeal joint. A tunnel is then made in the soft tissues on the inner side of the first *metatarsal bone posterior to its head and the proximal end of the extensor* tendon is rerouted through this tunnel onto the plantar aspect of the foot. Strong tension is exerted while the tendon is attached to the taut flexor tendon *with silk sutures.*

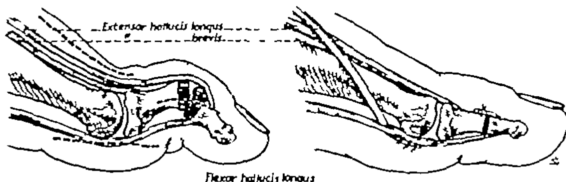


Fig. 891—Dickson Diveley operation for clawtoe deformity of great toe. Extensor hallucis longus is transferred and inserted into flexor hallucis longus tendon arthrodesis of interphalangeal joint, removing sufficient bone to correct deformity (Redrawn from Dickson, F D., and Diveley R. L. J. A. M. A. 87 1275, 1926.)

Finally through a small third incision on the medial aspect of the interphalangeal joint (instead the second incision may be extended along the dorsum of the great toe to the distal phalanx), the surfaces of the joint are resected sufficiently to permit arthrodesis of the joint with the toe in the neutral position. Following arthrodesis of the interphalangeal joint, the short distal portion of the extensor tendon is sutured to the soft tissues on the dorsal aspect of the first phalanx assisting in maintenance of apposition of the raw osseous surfaces.

After Treatment.—*A plaster or metal splint* is applied, holding the metatarsophalangeal joint flexed and the interphalangeal joint extended. After the wound has healed physical therapy and exercises are instituted to strengthen the transplanted muscle, provided surgery has been limited to this operation. Weight-bearing is gradually resumed three weeks postoperatively with the aid of an arch support and metatarsal pad.

The principles embodied in the Jones operation for clawfoot (attachment of the extensor hallucis longus tendon into the first metatarsal bone) and for hammertoe (resection and arthrodesis of the interphalangeal joint) may be combined to apply to clawtoe deformity of the great toe. The extensor hallucis longus tendon is attached to the head of the first metatarsal bone the interphalangeal joint may or may not be fused

Fig. 809.—*A*, Varus deformity of foot, with clawtoe deformity of great toe on attempted dorsiflexion of foot and ankle. *B*, After triple arthrodesis and Dickson Diveley operation. Note marked improvement in weight bearing alignment of entire extremity.

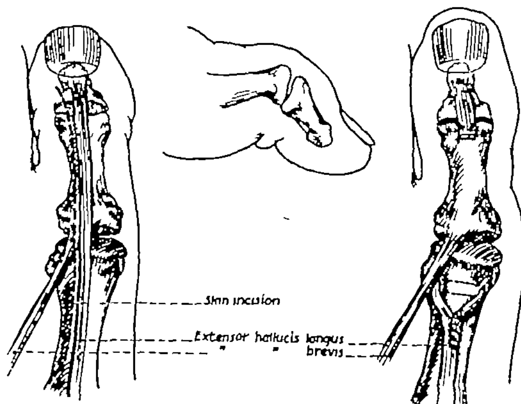


Fig. 810.—Modified Jones (Sir Robert) operation for clawtoe deformity of great toe. Extensor hallucis longus tendon inserted into head of first metatarsal bone; arthrodesis of interphalangeal joint; distal end of extensor tendon sutured to proximal phalanx to aid in maintaining position of joint surfaces.

Technic (Jones).—An incision is made along the lateral border of the extensor tendons of the great toe beginning just distal to the interphalangeal joint and extending two inches proximal to the metatarsophalangeal joint. The extensor hallucis longus tendon is exposed and severed at the level of the interphalangeal joint. A hole is then drilled through the head of the metatarsal bone from the dorsomedial surface obliquely downward and outward. A silk suture is placed in the end of the tendon and the free ends of the suture are passed through the drill hole in the bone by means of a wire loop. The tendon is drawn through this tunnel and sutured to itself while the foot is held in dorsiflexion; thus a complete loop of tendon is formed through the head of the metatarsal bone. The interphalangeal joint of the great toe should be arthrodesed. Flexion deformity of this joint cannot be prevented by tenodesis of the distal end of the tendon into the proximal phalanx alone. In addition to resection of the articular surfaces accessory fragments of bone obtained from the shaft of the first metatarsal or elsewhere may be packed into the denuded joint. The distal end of the severed tendon is sutured to the periosteum of the proximal phalanx or to the short extensor tendon. O'Donoghue and Stauffer insert a Kirschner wire longitudinally through the end of the toe traversing the distal phalanx, crossing the denuded joint and extending well into the proximal phalanx. The wire is clipped off just outside the skin surface and is allowed to remain until fusion of the joint is demonstrated roentgenographically (Fig. 903).

After Treatment.—See p. 1292.

Wagner notes that when the extensor hallucis longus tendon is transplanted to the head of the metatarsal bone the bone is elevated but the dorsiflexion is lost. To obviate this disability the extensor tendon of the fifth toe is transplanted to the base of the first phalanx.

Technic (Wagner).—An incision is made along the extensor hallucis longus tendon and this structure is divided as far distally as possible. A wedge-shaped arthrodesis is carried out through the interphalangeal joint, correcting the flexion contracture. The extensor hallucis longus tendon is passed through a drill hole one-fourth inch from the articular surface of the metatarsal head and sutured to itself. Through a second incision the extensor tendon to the fifth toe is freed from its attachments and drawn out through a small third incision just below the annular ligaments of the ankle joint. This tendon is then passed subcutaneously to the first incision and sutured to the dorsum of the base of the first phalanx.

After Treatment.—A small plaster boot is applied which maintains elevation of the metatarsal heads and immobilizes the toes in plantar flexion. After three weeks the cast is removed and the foot is placed in a walking cast, fixation of the toes in the corrected position being continued. Six to eight weeks postoperatively weight bearing is resumed in a shoe with a metatarsal bar attached.

The operation described by Forrester Brown is based on the principles suggested by Sir Harry Stiles for paralysis of the lumbrical muscles of the hand, namely transference of part of the flexor tendon to the extensor tendon opposite the first phalanx to permit flexion of the metatarsophalangeal joint and extension of the interphalangeal joint. As applied to clawtoe deformity the procedure consists of transference of the flexor hallucis longus tendon to a new insertion in the extensor hallucis longus tendon and arthrodesis of

the interphalangeal joint This technic is of course not appropriate if the long flexor tendon is even partially paralyzed

Technic (Forrester Brown)—The incision is begun at the internal cuneiform bone along the upper border of the abductor hallucis muscle and extended to the medial side of the great toe opposite the interphalangeal joint To provide adequate exposure of the flexor and extensor tendons, skin flaps are dissected toward both the dorsal and plantar surfaces of the foot. The flexor tendon is removed from its sheath proximally to the middle of the metatarsal bone and divided near its insertion into the phalanx. The extensor tendon is also lifted from its sheath and lengthened by the Z-plastic method The hyperextension deformity of the metatarsophalangeal joint is corrected by dorsal capsulotomy, and the flexion deformity of the interphalangeal joint is then corrected by resection of a wedge from the joint surfaces, including both cartilages. Approximation is maintained by sutures through the soft tissues. The flexor tendon is then rerouted from the middle of the metatarsal bone along the medial side of the metatarsophalangeal joint and attached to the extensor tendon on the dorsum of the proximal phalanx by a silk suture No attempt is made to close the tendon sheaths.

After Treatment.—The great toe is fixed in the neutral position by a firm bandage and the foot and ankle are immobilized for ten days in a splint which holds the foot at a right angle. The patient is kept in bed for a period of three weeks with the limb elevated massage and exercises are then begun

Cavus Deformity—Clawfoot

Clawfoot is a deformity of the foot arising from an ill-defined weakness or imbalance of one or several of the muscle groups, both intrinsic and extrinsic, which control the foot. The primary deformity is a forefoot drop" or equinus which results on weight bearing in a cavus deformity of the foot A typical clawing of the toes appears secondarily the interphalangeal joints being flexed while the metatarsophalangeal joints become hyperextended. The deformity of the toes disappears with early obliteration of the cavus, but persists when the deformity is of long standing and of more severe degree The cavus may be of any degree In advanced cases, large callosities and even ulcerations may develop beneath the metatarsal heads or marked clawing of the toes may result in a dorsal dislocation of the metatarsophalangeal joints an extreme degree of cavus may be associated with contracture of all the plantar structures.

Various etiologic factors are believed to be active in the production of this deformity usually however no one factor can be held directly responsible. The central nervous system is believed to be the site of the underlying pathology in most cases, spina bifida, infantile paralysis, and, less frequently certain of the myelodysplasias Friedreich's ataxia multiple sclerosis and even the progressive muscular atrophies being factors. It must be remembered that the clawfoot itself is only a symptom of the underlying condition and is not an entity in itself. In the true clawfoot, there is no real contracture or shortening of the tendo achillis unless the deformity is far advanced

The form of treatment indicated in the individual case varies with the severity of the deformity A mild deformity is hardly distinguishable from the normal foot with a high arch ' as the cavus and slight clawing of the toes disappear on weight bearing For this type conservative measures such as metatarsal bar on the shoe or an insole with a metatarsal pad during the

day and a night splint with a metatarsal bar, have been advised. These measures, however will not prevent increasing deformity if the lesion is a progressive one though *occasionally progression sooner or later ceases spontaneously*

Several operative procedures have been advocated for these mild cases, each being based on a theory of muscle imbalance. Bentzon is of the opinion that the deformity arises from an imbalance of the tibialis anticus and peroneus longus muscle function he advocates division of the tendon of the peroneus longus with imbrication of the proximal stump of the tendon into the tendon of the peroneus brevis Hallgrimsson points out that paralysis or weakness of the peroneus brevis from overstretching or other cause is compensated for by hypertrophy of the peroneus longus, but since the peroneus



Fig. 901.—For early clawtoes and cavus deformity of foot, interphalangeal joints of toes may be fused by intramedullary autogenous grafts.

longus is inserted into the base of the first metatarsal and into the plantar aspect of the first cuneiform bone this hypertrophy does not prevent a hind foot varus deformity nor pronation of the forefoot. On the other hand, Lambrinudi has advocated arthrodesis of the interphalangeal joints of all the toes (Fig 901) on the basis that the clawing of the toes arises from a paralysis or disturbance of function and balance of the intrinsic muscles of the foot particularly the lumbrical and interosseous groups, the cavus deformity being secondary Since the toes can no longer carry out their normal action of supporting the metatarsal heads, callosities develop and propulsive action of the toes in walking is lost Thus, according to Lambrinudi, treatment should be directed toward restoration of the essential function of the toes, which is normally carried out by the combined action of the intrinsic muscles and the long

flexors. By arthrodesis of the interphalangeal joints of the toes, the long flexors may exert their whole effect upon the metatarsophalangeal joints thus the normal support to the metatarsal heads is restored when the toes are pressed to the ground

In the presence of moderate cavus wherein the deformity is more pronounced and fixed though associated with only a mild, fixed clawing of the toes a subcutaneous plantar fasciotomy is performed, the cavus is corrected by manipulation, and the foot is immobilized in plaster Since this procedure is preventive and is less effective after the deformity has further progressed arthrodesis of the interphalangeal joints of the toes may be indicated at this stage.

For more severe deformities which cannot be corrected satisfactorily by plantar fasciotomy alone a Steindler stripping (p 1298) is performed in conjunction with an anterior wedge osteotomy of the tarsus (Fig 924) or the anterior wedge osteotomy alone may be carried out If necessary a modified Hibbs transference of the toe extensors into the cuneiform bones and an arthrodesis of the interphalangeal joint of the great toe may be done. In varus deformity of the hindfoot the anterior tarsal wedge resection is contraindicated rather a triple arthrodesis or foot stabilization should be performed.

In severe deformity with a varus of the heel and forefoot, the Steindler stripping is combined with stabilization the proximal interphalangeal joints are excised to correct the clawing of the toes in conjunction with a dorsal capsulotomy of the metatarsophalangeal joints these procedures are combined with a modified Hibbs tendon transference of the long toe extensors In the presence of ulceration of the skin beneath the metatarsal heads and contracture of the tendo achillis, in addition to the above-mentioned measures, lengthening of the tendo achillis and even resection of the metatarsal heads after the method of Hoffman (p 841) may occasionally be necessary Amputation is rarely indicated and then only as a last resort.

Tenotomy and Fasciotomy for Pes Cavus

Tenotomy and fasciotomy generally are carried out in conjunction with extensive operations on the tarsal bones for cavus or calcaneovalgus deformities they are also employed independently for mild types of clawfoot or cavus when operations upon other joints necessitate correction by a simple procedure, to avoid undue prolongation of the operation. Overcorrection of the deformity is not desirable as a flat foot or rocker bottom foot would be thus produced. The procedure is in reality a subcutaneous Steindler operation.

Technic.—With the hip in 150 degrees' flexion and the knee in extension the foot is forced into extreme dorsiflexion to place the contracted fascia and flexor brevis digitorum muscles under tension A tenotomy knife or small scalpel is inserted on the inner aspect of the heel, and the common origin of the short flexor tendons to the toes and the plantar fascia are divided transversely to the bone. The knife is then turned with its cutting edge forward and all structures are severed close to the bone a distance of one or more inches. By palpation one may ascertain several taut bands of plantar fascia usually one or more being found near the external border of the foot These are divided individually

If desired the incision may be enlarged for the next step in the operation. A periosteal elevator one half inch wide is inserted and all structures are

stripped subperiosteally from the os calcis to its anterior extremity The cavus or clawfoot deformity is then forcibly corrected by extreme dorsiflexion of the foot.

After Treatment.—A boot cast which holds the foot in the corrected position is worn for a period of six weeks. Physical therapy is then instituted and walking resumed with the aid of a metatarsal pad

Steindler Operation for Pes Cavus

The stripping operation described by Steindler for pes cavus is much more scientific than subcutaneous tenotomy and fasciotomy as the structures on the plantar aspect of the foot are divided under direct vision In deformities of moderate degree the procedure is employed alone. In extreme and rigid deformities, wherein the tarsal bones are misshapen the Steindler technic may be combined with reconstruction of the tarsal bones. This method may also be employed in equinovarus deformities with contracture of the plantar structures.

Technic.—A horizontal incision is made over the inner aspect of the os calcis and carried forward to a point one and one-half inches anterior to its inner tubercle. The under surface of the plantar fascia is separated from the layer of fat and freed throughout its breadth The fascia is then incised crosswise close to the point where it blends into the lower surface of the os calcis. The muscles covered by the plantar fascia are, from within outward, the abductor of the great toe the short flexors of the toes, and the abductor of the fifth toe these are stripped from the periosteum of the os calcis with a blunt instrument Dissection is continued to the calcaneocuboid junction to include the long plantar ligament which extends between the os calcis and the cuboid bone. This ligament is often contracted producing a convexity of the foot at the outer border By dissection close to the bone, the plantar vessels and nerves will not be injured. When all the structures have been separated the foot is forced into the corrected position.

Removal of cortical bone with the fascia and muscle attachments should be avoided otherwise excess bone may form on the plantar surface of the os calcis and cause pain on weight bearing This complication need not occur however if a blunt instrument is used or if the muscles are separated close to the periosteum with a scalpel rather than with a keen-edged chisel.

Tendon Transference for Clawtoes and Cavus (Clawfoot)

Tendon transference by the following technics is particularly advantageous in cavus deformities associated with clawtoes in that, not only are the deformities of the toes and longitudinal arch corrected but the disproportion in muscle power may be equalized. In the majority of these procedures the extensor tendons are utilized being reinserted into the heads of the metatarsal bones. Thus, the extensor tendons to the toes dorsiflex the forefoot and ankle and, provided muscle balance is well established, prevent recurrence of the deformity

Sherman in 1904 described such a procedure, establishing the principles which formed a basis for subsequent, more efficient operations by Watkins, in 1912 Forbes, in 1913 Jones, in 1916 Hibbs, in 1919, and Heyman, in 1932. Numerous minor variations of these technics have since been devised

Technic (Sherman) —The cavus deformity is corrected by subcutaneous division of the plantar structures, as just described. Sterile gauze squares

are placed about the foot next the skin, that they may be folded back later The foot is then immobilized in a plaster boot which maintains the corrected position, the dorsal part of the cast is removed the sterile gauze folded back and drapes applied

A quadrilateral flap with its base at the tarsometatarsal line, is now formed by an incision extending along the outer side of the fifth metatarsal bone across the foot at the metatarsophalangeal joints, thence continuing proximally along the inner side of the first metatarsal bone The flap is dissected up exposing the extensor tendons as they traverse the metatarsus. The extensor hallucis longus tendon is removed from its sheath and divided just proximal to the head of the first metatarsal bone The periosteum is in cised in line with the bone and stripped free on both sides. Two chromic

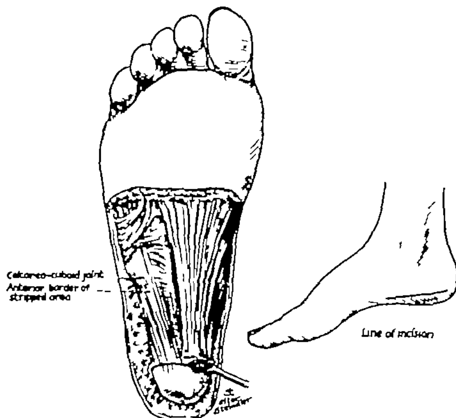


Fig 902.—Steindler stripping operation for pes cavus. Exposure by medial incision subperiosteal stripping of long plantar ligament and origins of short plantar muscles. (Redrawn from Steindler Arthur J Orthop. Surg. 21 1 1920)

catgut sutures on long straight needles are inserted through the proximal end of the tendon, the distal suture 1 cm. and the proximal suture 2 cm from the cut edge. The sutures are then passed on each side of the bone be neath the reflected periosteum through the sole of the foot and the plantar part of the plaster splint, and tied. When these sutures are drawn taut, the tendon is held tightly to the denuded bone and partially covered by the flaps of the periosteum. The other tendons are treated in a similar manner

After Treatment.—Dressings are applied and the dorsal window is replaced. The foot should be held in slight dorsiflexion at the ankle.

The procedure which was described in 1904 may be modified to conform to the present conception of surgical technic, *as follows* The extensor tendons and the metatarsophalangeal joints are exposed by longitudinal in cisions, one parallel to the extensor hallucis longus tendon, a second between

the second and third metatarsal bones, and a third between the fourth and fifth metatarsal bones. After division of the extensor tendons, the dorsal capsule of the metatarsophalangeal joints is incised transversely and the flexor tendons of the second third fourth and fifth toes are divided with a tenotomy knife beneath the flexed phalangeal joints. The contractures of the toes are then forcibly corrected The phalangeal joint of the great toe is resected, the flexion deformity corrected and fusion allowed to take place with the bones in a straight position. The ends of the extensor tendons are attached to the heads of the metatarsal bones by sutures through holes drilled in the bone. If the tendons are of sufficient length, they may be passed through the bone and sutured to themselves. Little difficulty is encountered in drilling transverse holes through the first and fifth metatarsal bones. In the second third, and fourth metatarsal bones, a hole is drilled on each side in an oblique plane so as to meet in the center of the bone.

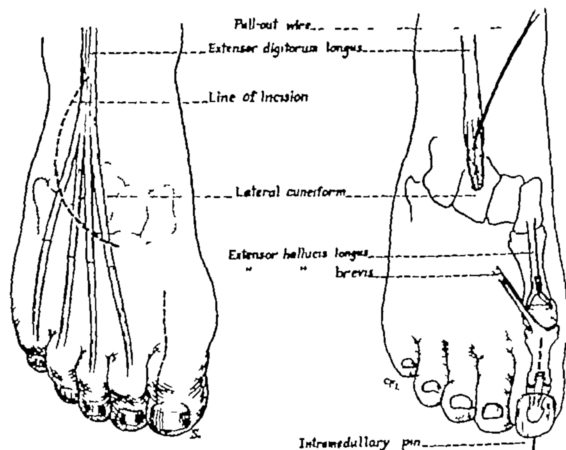


Fig. 303.—Hibb's operation for clawtoes and cavus deformity (clawfoot) Tendons of extensor digitorum longus divided and their proximal ends inserted as a group into lateral cuneiform bone according to method of Cole. Extensor hallucis longus divided and fixed to first metatarsal bone. Arthrodesis of distal phalangeal joint of great toe Intramedullary pin used for fixation.

This modification of the Sherman technic is similar to the procedures described by Watkins, Forbes, and Heyman. No originality is claimed.

In the operation for cavus deformity described by Jones, in 1916 only the extensor hallucis longus tendon was attached to the head of the metatarsal bone.

Technic (Jones) —A plantar fasciotomy is first performed and the plantar structures stretched. An incision is then made along the extensor hallucis

longus and the tendon severed from its attachments. With a drill, a tunnel is formed through the first metatarsal bone just proximal to the head The tendon is passed through this tunnel by means of a ligature drawn taut and sutured to itself (Fig 900)

After Treatment.—The foot is bandaged firmly to a metal sole plate a thick roll of wool being placed transversely just behind the heads of the metatarsal bones. After the stitches are removed, the foot is immobilized in the corrected position by a plaster cast. Walking is then permitted for a period of three to six weeks. Thereafter a bar is attached across the sole of the shoe beneath the heads of the metatarsal bones, and the heel is removed from the shoe in order to hold the foot in slight dorsiflexion on walking

Hibbs severed the tendons of the extensor digitorum longus muscle and reattached them as a group to the lateral cuneiform bone.

Technic (Hibbs)—The plantar structures are separated from their attachments to the os calcis, as described The forefoot is forcibly elevated the exaggerated arch corrected and the position of the metatarsals improved. A curved incision three to four inches in length, is made on the dorsum of the foot to the outer side of the medial line and the common extensor tendons are exposed The tendons are divided low and their proximal ends are drawn through a tunnel in the external cuneiform bone and fixed by a silk suture

After Treatment.—With the metatarsal bones in a corrected position, the foot is immobilized in a plaster cast for a period of six weeks. Physical therapy is then begun and continued for an additional six weeks.

TENDON TRANSFERENCE

Tendon transference about the foot and ankle generally is supplemented by stabilizing procedures to correct fixed deformities, establish sufficient lateral stability for weight bearing and partially compensate for the loss of power in the abductor-evertor and adductor invertor muscles. In addition when tendons are transferred to the dorsum of the foot to produce active dorsiflexion the bone block operation is carried out, if necessary to limit plantar flexion and prevent over-stretching of the transferred tendons. When tendon transference and correction of an osseous deformity or stabilization are combined at the same operation the latter is performed first.

In general, in the presence of any muscle imbalance, tendon transposition of even one muscle should be preceded or accompanied by a stabilization of the foot. It is impossible to balance the muscle power about the foot with absolute accuracy by tendon transposition alone. After stabilization of a foot, only plantar flexion and dorsiflexion which are ankle motions, remain, and muscle power on the medial and lateral aspects of the ankle joint is unnecessary An exception to this is found in the true cavus or clawfoot here, an anterior tarsal wedge osteotomy is performed, subastragalar and midtarsal motion being preserved.

Transposition is preferable to excision of a tendon in that not only is function preserved but further atrophy of the leg is prevented. If the paralysis or muscle weakness is sufficient to require stabilization, some weakness of either dorsiflexor or plantarflexor muscles or both is usually associated and invertor or evertor muscles should be transferred by tendon transposition to the midline of the foot or into the os calcis and tendo achillis. In the event a muscle is to be discarded, at least three or four inches of its tendon should be excised to prevent reunion of the tendon ends by fibrous tissue

Accompanying deformities of the leg in particular, excessive tibial torsion, knock knee or bowleg should be corrected following foot stabilization and tendon transposition since, if uncorrected these may cause recurrence of foot deformity

Peabody classified paralysis of the muscles of the foot and ankle as follows those with (1) limited extensor invertor insufficiency, (2) gross extensor invertor insufficiency, (3) evertor insufficiency, and (4) triceps surae (tendo achillis) insufficiency He offered the following suggestions as to treatment

1 **Limited Extensor Invertor Insufficiency**—This type consists of severe weakness or paralysis of the tibialis anticus muscle with a slowly progressive deformity, i e equinus and cavus, or varying degrees of planovalgus. Muscle power is redistributed by transposition of the extensor hallucis longus tendon to the base of the first metatarsal bone Other than plantar fasciotomy no operative procedure is employed as a rule, since this alone gives satisfactory postural and functional results. In the presence of a severely relaxed foot or fixed valgus deformity, tendon transference is combined with astragaloscaphoid arthrodesis. In the majority of cases, the equinus deformity may be corrected by stretching prior to operation in others, tenotomy or lengthening of the tendo achillis may be necessary

2. **Gross Extensor Invertor Insufficiency**—*(Type A)* Weakness and paralysis of the tibialis anticus muscle and extensors of the toes, with a relatively normal tibialis posticus, produces a paralytic equinus or equinovalgus deformity Secondary redistribution of muscle power is secured by transposition of the *peroneus longus tendon to the dorsum of the foot.* The latter is not passed through the sheath to the insertion of the tibialis anticus, as such a procedure might reverse the invertor-evertor imbalance and leave the foot unstable in a varus position Rather the tendon usually is inserted on the dorsal aspect of the medial cuneiform bone. If the structural changes of the soft tissues and bone prevent satisfactory alignment, astragaloscaphoid arthrodesis may be combined with tendon transposition.

(Type B) A severe paralysis of both tibial tendons as well as the toe extensors characterizes this type Transposition of both peroneal muscles to the dorsum of the foot should permit good function. For a severe deformity of long standing the Hoke type of arthrodesis may be combined with tendon transposition.

3 **Evertor Insufficiency**—For loss of power in the peroneal muscles, the extensor hallucis longus or tibialis anticus muscle is transposed *to the outer* side of the foot. If the impairment is slight or moderate in degree, the extensor hallucis longus tendon is transferred to the base of the fifth metatarsal bone. In the presence of gross impairment, the tibialis anticus tendon is transposed *to the cuboid and the extensor hallucis longus* to the first metatarsal bone. When the power of the peroneal muscles is completely lost and the tibialis posticus remains normal greater security against varus imbalance is obtained by tenotomy of the posterior tibial tendon. In a varus deformity of long standing the tarsal bones are stabilized by arthrodesis.

4. **Triceps Surae or Tendo Achillis Insufficiency**—Peabody is convinced that redistribution of muscle power in the early postparalytic stage (two to three years) will prevent a progressive calcaneus or calcaneocavus deformity In his experience the only operation which will restore complete heel-and toe gait and tiptoe capacity is the *transposition of the tibialis anticus through* the tendo achillis to the os calcis further perhaps restoration of this func

tion would be more perfect by the additional transposition of the extensor hallucis longus tendon to the dorsum of the foot, provided the muscle is competent. In calcaneovalgus deformity, the peroneal tendons are attached to the os calcis. For calcaneovarus imbalance, both the tibialis posticus and flexor hallucis longus tendons are transposed. Calcaneocavus deformity wherein both the invertors and evertors are strong is corrected by transposition of the peroneal and tibialis posticus tendons to the os calcis. In deformities of long standing correction of the skeletal distortion is also necessary

Summarizing the results of tendon transposition for calcaneus insufficiency, Peabody presented the following recommendations (1) in early cases without skeletal distortion wherein only the achillis group are weak, posterior transposition of the tibialis anterior without bone surgery (2) in early cases with complicating lateral imbalance, transposition of the acting evertors or invertors, as the case might be (3) in old cases with associated bony deformities wherein muscle status is that described in (2) supplementary resections and arthrodesis of the tarsal joint and (4) in old cases with a muscle status as described in (1), a combination of tarsal reconstruction with posterior transposition of the peroneus longus and the tibialis posticus tendons. With the exception of tarsal reconstruction and posterior transposition of the tibialis anticus tendon these procedures may be carried out at a single operation.

Tendon Transference of Tibialis Anticus Tendon for Paralysis of Peroneal Muscles

This procedure is indicated in the presence of a varus or equinovarus deformity for paralysis or weakness of the peroneal muscles while the activity of the tibialis anticus and tibialis posticus muscles remains normal.

Technic.—A two-inch incision is made along the medial border of the foot at the joint between the medial cuneiform and first metatarsal bones. The insertion of the tibialis anticus tendon is located on the under surface of these bones and divided. The anterior aspect of the lower third of the leg is then incised in the midline a distance of three inches, exposing the tendons of the tibialis anticus, extensor hallucis longus, and extensor digitorum longus muscles from within outward. The sheath of the tibialis anticus tendon is opened, the tendon is elevated with a hemostat, and, by steady traction, is withdrawn from the wound.

A third incision is now made over the anterolateral aspect of the foot, exposing the mid tarsus. Dissection is carried toward the midline and the sheath of the extensor digitorum longus tendon is incised. A hemostat is passed proximally within the sheath toward the second incision on the lower third of the leg Through the second incision the sheath is split over the end of the hemostat sufficiently to admit the hemostat into the wound. The free end of the tibialis anticus tendon is grasped and drawn through the sheath of the extensor digitorum longus tendon into the wound on the lateral aspect of the foot. With a No 19 drill and a curette a tunnel is next made through the cuboid bone from above downward and outward. Sutures of silk are stitched in the end of the tendon thence proximally, following the inner border across the tendon and distally along the opposite side By means of a wire loop the two ends of the sutures are drawn through the tunnel from above downward With the foot in dorsiflexion the tendon is next brought through the tunnel and if possible, sutured to itself above under physiologic tension When the tendon

is not of sufficient length to be united in this manner the tendon of the peroneus brevis is divided behind the lateral malleolus and its distal segment is transposed anteriorly for suture to the tibialis anticus tendon This method was described by White and is useful for adding length and insuring proper insertion of the tranferred tibialis anticus tendon

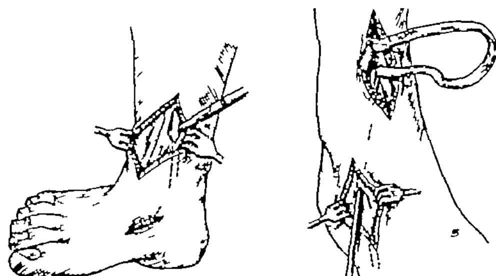


Fig. 904—Transference of tibialis anticus tendon for paralysis of peroneal muscles. Insertion of tendon detached, rerouted from just above ankle to lateral side of foot, and reattached.

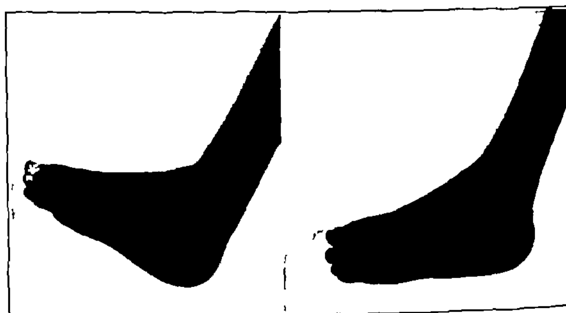


Fig. 905.—Range of active motion following transference of tibialis anticus tendon to lateral side of foot, and triple arthrodesis.

When this procedure is combined with triple arthrodesis, the tunnel in the cuboid bone may be made from the posterior cancellous surface to the superior surface, and the tendon passed through and fixed in the manner described Thus, a portion of the tendon lies between the posterior and anterior cancellous surfaces of the cuboid and os calcis, respectively

In order to prevent postoperative valgus or planovalgus deformity O'Donoghue recommends posterior transference of the extensor hallucis longus

tendon when the anterior tibial tendon is transferred to the lateral border of the foot. The tendon of the extensor hallucis longus is transferred through the tibialis anticus sheath into the tibialis anticus insertion, and the inter phalangeal joint of the great toe is arthrodesed

After Treatment—The foot is held at a right angle to the leg and placed in a boot cast. If the operation has consisted of tendon transference alone, the cast is bivalved at the end of three weeks and physical therapy and active and passive exercises begun, with due care that the tendon is not placed under excessive strain At the end of six weeks, an ankle brace is fitted a drop foot catch being attached to prevent plantar flexion At night and between exercise periods, the back half of the bivalved cast or splint is worn to keep the foot at a right angle Apparatus is not discarded until active dorsiflexion of the foot to a right angle is possible Usually this requires at least six months.

If stabilizing procedures have supplemented the tendon transference, muscle re-education and physical therapy are delayed for eight weeks After treatment is then carried out as described

This operation is perhaps the most uniformly successful of all tendon transferences in the region of the foot.

Transference of the Peroneus Longus Tendon for Paralysis of the Tibialis Anticus Muscle

When function in the tibialis anticus muscle is lost the action of the peroneal muscles leads to abduction of the forefoot, eversion of the heel and tarsus, and depression of the longitudinal arch. In this condition, tendon transference alone is rarely sufficient. To realign the foot and restore the normal longitudinal arch, a midtarsal or triple arthrodesis may also be necessary

Technic.—Beginning over the calcaneocuboid joint, the lateral border of the foot is incised longitudinally a distance of two inches. (When triple arthrodesis is to be performed in conjunction with this transference, the routine incision for stabilization is made.) The peroneus longus tendon is identified as it curves under the inferior surface of the cuboid bone and with the foot abducted, is severed as far distally as possible. A second longitudinal incision three inches in length is made on the anterolateral aspect of the leg between the middle and lower thirds, and the peroneus longus, the more superficial of the peroneal tendons, is identified at its musculotendinous juncture. The sheath is incised and the tendon withdrawn from the wound

A third incision, three inches in length is now made over the normal insertion of the tibialis anticus tendon into the base of the medial cuneiform bone and the base of the first metatarsal bone The sheath of the tendon is incised and a special tendon carrier or Kelly clamp is passed from the third incision through the sheath of the tibialis anticus muscle, into the second incision. The free end of the peroneus longus tendon is grasped and drawn through the sheath of the tibialis anticus tendon, to emerge in the third incision at the insertion of this structure By means of a No 19 drill and a small curette a tunnel is made in the first cuneiform bone from above downward The peroneus longus tendon is passed through this hole from the plantar to the dorsal surface of the bone and fixed as described above for transference of the tibialis anticus tendon. The foot is held in adduction and dorsiflexion while the tendon is sutured.

A midtarsal arthrodesis may be carried out through the first and third incisions, for fusion of the calcaneocuboid and astragaloscaphoid joints, respectively If triple arthrodesis is employed the first incision is extended proximally and upward to expose the subastragalar joint When tendon transference and arthrodesis are combined the latter is carried out first

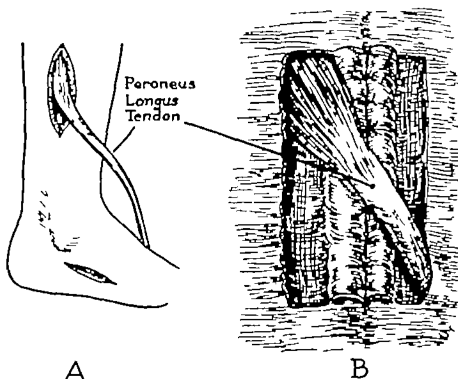


Fig. 906.—Transference of peroneus longus tendon for paralysis of tibialis anticus muscle. A Peroneus longus tendon detached at level of cuboid bone and withdrawn from a second longitudinal incision on anterolateral aspect of leg. *B* Biesalski-Mayer method of forming smooth gliding surface for transplanted tendon. Fascia incised over peroneal compartment, then over anterior muscular compartment. Flaps sutured together as indicated, the deep surface covered with paratenon being everted.

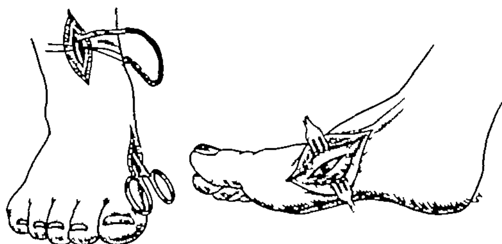


Fig. 907.—Same as Fig 906 Tendon drawn through sheath of tibialis anticus and inserted on medial side of foot.

Peabody and McCarroll have abandoned transference of the peroneals through the sheath of the tibialis anticus. Since the degree of muscle imbalance is difficult to determine a reversal of the valgus deformity to varus may occur

when the peroneus longus tendon is transferred to the inner side of the foot Instead one or both peroneal tendons are passed through the subcutaneous tissues over the anterior surface of the ankle beneath the anterior crural ligament to the dorsum of the foot then reattached through a tunnel to the medial side of the middle cuneiform bone, or as occasion may demand to the medial cuneiform bone

Tendon transference into the tarsus is most easily accomplished by the method of Cole (Fig 103)

If power remains in the tibialis anticus muscle, transference of the peronei should be accompanied by transference of the tibialis anticus tendon into the center of the tarsus to prevent elevation of the shaft of the first metatarsal and hallux equinus deformity



Fig. 108 —Range of active motion following transference of peroneus longus muscle.

After Treatment.—The foot is immobilized in a boot cast at a right angle to the leg and in slight adduction and inversion. The subsequent treatment differs little from that described for transference of the tibialis anticus tendon an arch support is placed in the shoe and an inner T strap applied to the brace after six to eight weeks.

This procedure is less correct mechanically than transference of the tibialis anticus tendon and, although function may be excellent, the result is less dependable

Tendon Transference for Paralysis of Tibialis Anticus and Posticus Muscles

If paralysis or weakness of the tibialis posticus muscle is associated with paralysis of the tibialis anticus muscle, the transference of the peroneus longus tendon as described previously is supplemented by transference of the insertion of the extensor hallucis longus tendon into the head of the first

metatarsal bone When the tibialis anticus muscle is only partially paralyzed and active dorsiflexion is incomplete while the remaining muscles of the foot and ankle are normal, transference of the extensor hallucis longus tendon may add sufficient power to permit complete active dorsiflexion of the ankle.

Technic.—An incision three inches in length is made along the medial surface of the first metatarsal bone The extensor hallucis longus tendon is identified and its sheath incised throughout the length of the incision. A second incision is made over the dorsum of the interphalangeal joint of the great toe and the tendon is severed just proximal to the interphalangeal joint and withdrawn through the first incision. A tunnel is created in the metatarsal bone from above downward just proximal to the head The free end of the extensor tendon is then drawn through the inferior opening of the tunnel to emerge on the dorsum of the first metatarsal bone and sutured to the adjacent soft tissue According to Ober the tendon should not be sutured to itself, as the power of inversion and adduction would be reduced in so doing.

To prevent hammertoe deformity the distal end of the severed tendon is sutured to the soft tissue on the dorsum of the proximal phalanx and the interphalangeal joint is arthrodesed

After Treatment.—See above

Steindler utilizes the extensor hallucis longus muscle for weakness of the tibialis anticus in a slightly different manner

Technic (Steindler).—An incision is made between the extensor hallucis longus and tibialis anticus muscles, the sheaths are opened and the apposing edges of the tendons are scarified. The extensor hallucis longus tendon is then severed distally and sutured side-to-side to the tibialis anticus tendon. The interphalangeal joint of the great toe is arthrodesed.

Forward Transference of the Tibialis Posticus Tendon

In equinovarus deformity associated with normal power in the gastrocnemius and posterior tibialis muscles, and paralysis of the tibialis anticus and peroneal muscles, the only possibility of securing active dorsiflexion lies in transference of the tibialis posticus tendon to a forward position. This, however is not entirely dependable. If the long extensors to the toes are active, the transference may be supplemented by the Hibbs operation *for clawtoes* (p 1301) to increase the power of dorsiflexion. The following procedure should be combined with a triple arthrodesis and bone block.

Technic (Ober).—Through a three-inch longitudinal incision over the medial aspect of the foot the tibialis posticus tendon is freed at its attachment to the scaphoid. A second incision four inches in length is made on the medial aspect of the leg the center of the incision being over the junction of the tibialis posticus tendon with its muscle. *The tendon is withdrawn from* the proximal wound and its belly is dissected free well up on the tibia. The periosteum on the medial surface of the tibia is stripped in an oblique direction, so that only the belly of the muscle will come in contact with denuded bone and the tendon will enter the anterior tibial compartment. The tendon *must not* be in contact with the tibia.

A third incision is made over the base of the third metatarsal bone, the tibialis *posticus tendon is drawn from the* second into the third incision and its distal end fixed into the base of the third metatarsal bone.

Hatt has modified this procedure by anchoring the transferred tibialis posticus tendon into the middle cuneiform bone rather than into the base of the third metatarsal bone He employs Cole's method of tendon anchorage, reinforced by several stay sutures at the point of entrance of the transferred tendon into the bone.

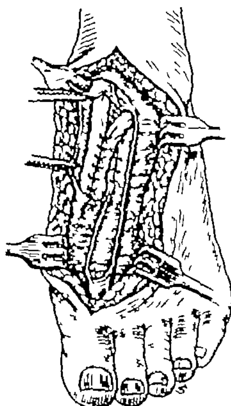


Fig. 909 —Transference of extensor hallucis longus tendon for weakness of tibialis anticus muscle (Steindler) Sheaths of adjacent tendons opened, extensor hallucis longus divided and sutured to tibialis anticus tendon. (Redrawn from Horsley J S., and Bigger I. A. Operative Surgery p. 205, St. Louis, 1927 The C. V Mosby Co.)

Tendon Transference for Paralysis of the Gastrocnemius Muscle

Paralysis of the gastrocnemius muscle usually is accompanied by a calcaneus or calcaneocavus deformity Any tendon transference for paralysis of this muscle must of necessity be accompanied by a stabilizing procedure which corrects the calcaneus deformity and balances the foot by backward displacement on the leg This may be accomplished by means of the Whitman astragalectomy or reconstruction of the tarsal joints. Regardless of the muscle or muscles transplanted to the tendo achillis, restoration of the normal power of plantar flexion is practically impossible.

Technic (Ober) —The tendons of the peroneus longus and tibialis posticus muscles are freed from their insertions up to the junctions of the muscles and tendons, as described above Either the medial or lateral incision on the foot is continued around the internal or external malleolus, as the case may demand, exposing the os calcis and tendo achillis. A hole is then drilled transversely through the os calcis near the insertion of the tendo achillis The peroneus longus and tibialis posticus tendons are passed downward through the sheath of the tendo achillis, *crossed behind the tendon*, then drawn through the hole in the os calcis thus, the tibialis posticus tendon is passed through the tunnel from the lateral to the medial side and the peroneal tendon from the medial to the lateral side. The free ends of the tendons are sutured to the os calcis or to the tendo achillis.

After Treatment.—See below

Mayer follows a technic resembling that of Ober, but utilizes four ten if possible the peroneus longus and brevis, and two of the three inner g i e., tibialis posticus, flexor digitorum longus, and flexor hallucis longus.

Technic (Mayer)—With the patient in the prone position, a two curved incision is made over the tendo achillis. The tendon is split l tudinally for one inch and a trap door of cortex is removed from t calcis for subsequent fixation of the transferred tendons. A second inc four inches in length, is made over the course of the peroneal tendons two inches above to two inches below the external malleolus. With the

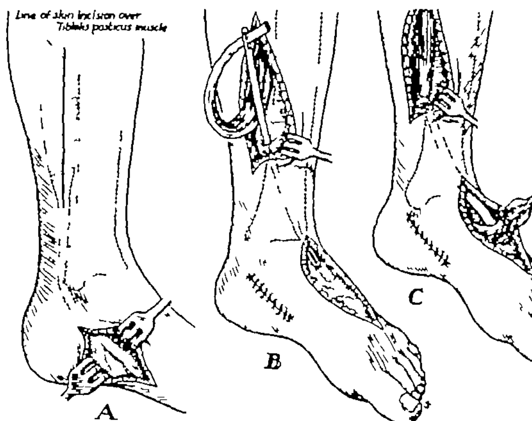


Fig. 910.—Forward tranference of tibialis posticus tendon (technic of Ober) *A* sure of tibialis posticus tendon. *B*, Belly of muscle dissected free from tibia and through anterior tibial compartment to dorsum of foot. *C* Insertion of posterior tibial into second and third metatarsal bones. (Redrawn from Ober F R.: New England J *Med* 52, 1932.)

in abduction, the sheath is incised, the tendons divided at the distal end o incision, and their free ends passed subcutaneously and sutured to the den area in the os calcis. A third incision also four inches in length, is i over the inner aspect of the ankle, exposing the tibialis posticus, fl digitorum longus, and flexor hallucis longus tendons If the flexor hal longus is to be transferred, the incision should be placed nearer the heel. of these tendons are freed from their sheaths, divided, and drawn thr subcutaneous tunnels to the first incision All the transferred tendons are fixed by sutures through slits in the lateral and medial borders of the t achillis and into the trap door in the os calcis.

After Treatment.—See below

Posterior Transference of Tibialis Anticus Tendon for Weakness or Paralysis of the Triceps Surae

Peabody has described a method of transferring the tibialis anticus tendon posteriorly into the tendo achillis which has proved very successful in a substantial series of cases in this clinic. Many of these children have regained the ability to walk on tiptoe and even though this ability has not been regained in all the calcaneus limp has been materially decreased and progressive deformity of the foot prevented In some cases active and passive dorsiflexion at the ankle has been restricted to a right angle Stabilization of the foot for lateral imbalance has been necessary in comparatively few cases. This operation may of course be performed before the age at which a stabilization can be done and in the event a stabilization proves necessary later there is little if any tarsal deformity to be corrected The experience of Peabody that varus instability does not develop has been verified in our series. In all probability varus instability would develop only in the presence of complete peroneal paralysis associated with normal power in the tibialis posticus and the long flexors of the toes. In the presence of a weak tibialis posticus and normal peroneal muscle power however valgus instability will develop This may be corrected by transplantation of the peroneus longus into the tendo achillis. In such cases, the distal stump of the peroneus longus should be imbricated into the peroneus brevis tendon to prevent elevation of the first metatarsal and hallux equinus.

Retraction of the toes from substitution of the long toe extensors in dorsiflexor function has not occurred in this series probably because function of the short toe flexors has been preserved

Technic (Peabody) —A small incision is made on the medial aspect of the foot over the insertion of the tibialis anticus tendon into the medial cuneiform bone and the tendon is detached so as to preserve as much of its length as possible. Through a long anterior longitudinal incision overlying the middle two-thirds of the leg the sheath of the tibialis anticus is incised parallel with the tibial crest By gentle retraction the tendon is drawn out through its distal sheath into the wound and is protected with a moist gauze sponge. The tendon and belly are mobilized in the anterior compartment to the junction of the middle and upper thirds of the leg with care to avoid injury to either the neurovascular bundle which enters the muscle belly in its middle third or the anterior tibial artery and vein which lie just lateral to the muscle on the interosseous membrane in the upper half of the leg A long trap door is raised from the interosseous membrane over the whole middle third of the leg It will be noted that some fibers of the tibialis anticus may take origin from the membrane though its posterior surface is free. The trap door is prepared as follows A longitudinal incision is made in the membrane directly at its tibial attachment, with transverse incisions to the fibula proximally and distally This flap is then turned up laterally and tacked with a few fine plain catgut or silk sutures to the digital extensor aponeurosis the free edge of the flap being prevented from coming in contact with the transferred tendon. By blunt dissection a tunnel is now formed from this incision along the paralyzed soleus muscle to the region of the tendo achillis. A posterolateral incision is next made along the tendo achillis down to the os calcis and the tendon is exposed The tibialis anticus tendon is then brought through the interosseous space without angulation or torsion care being taken that the vascular supply is

not damaged at this stage The tendon is imbricated into the tendo achillis and is anchored into the os calcis maintaining the foot in extreme plantar flexion. It has been our experience that the tendon is best anchored by the method of Cole (Fig 103)

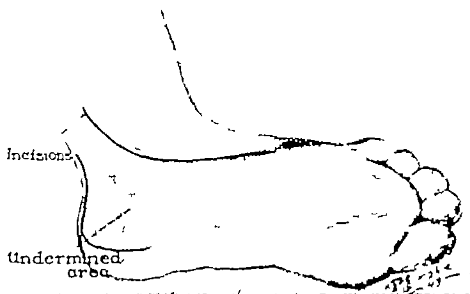


Fig. 911.—Transference of peroneus longus tendon for weakness or paralysis of the triceps surae. Line of skin incisions indicated. Stippled area represents area of skin which must be undermined. (From Bickel, W H., and Moe, J H.: Surg., Gynec. & Obst. 78 627 1944)

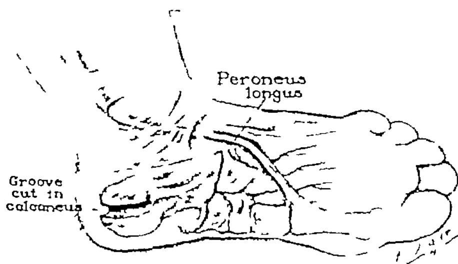


Fig. 912.—Same as Fig 911 Groove in os calcis prepared for peroneus longus tendon. (From Bickel, W H and Moe, J H. Surg., Gynec. & Obst. 78 627 1944)

After Treatment.—The extremity is immobilized in a cast extending from the midthigh to the toes, with the knee slightly flexed and the ankle in complete plantar flexion. The cast is bivalved at the end of three weeks to permit muscle re-education. Following this procedure, muscle re-education is highly important since the function of the tibialis anticus muscle is completely reversed. *At six to eight weeks postoperatively* walking is begun in an ankle brace, which prevents dorsiflexion and has an elevated heel. An adjustable

calcaneus stop is preferable the plantarflexed position being decreased each month by a progressive reduction of the heel of the shoe until the foot is flat thereafter, the brace should maintain this range for another three months

Translocation of the Peroneus Longus Tendon for Weakness or Paralysis of the Triceps Surae

Bickel and Moe have utilized von Baeyer's tendon translocation in an effort to obtain active plantar flexion in a foot which has developed a calcaneus deformity following paralysis of the gastrocnemius and soleus muscles In this procedure the tendon of the peroneus longus is rerouted from its course behind the lateral malleolus into a groove in the apex of the tuberosity of the os calcis thus converting an evertor into a plantar flexor No tendon suture is required and von Baeyer has expressed the opinion that the tension under which the translocated tendon and its muscle are placed causes the muscle to hypertrophy and thereby to function more effectively

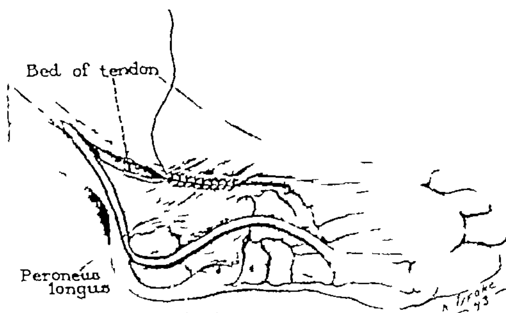


Fig. 913 —Same as Fig. 911 Tendon transferred to prepared groove. Peroneal retinaculum repaired. (From Bickel, W H., and Moe, J H. Surg Gynec. & Obst. 78 637 1944)

One definite disadvantage which these authors have encountered, however is the frequent development of necrosis of the edges of the undermined skin flap This has been partially obviated by placing the incisions as far apart as possible and by keeping the subcutaneous tunneling close to the bone

The best results have been obtained in patients with slight remaining power in the gastrocnemius muscle and fair or better power in the translocated peroneus longus.

Technic (Bickel and Moe) —A *curved incision* is made over the course of the peroneal tendons, from two inches above the lateral malleolus to the point where the peroneus longus passes beneath the cuboid into the sole of the foot. The peroneal retinaculum is split and the peroneus longus tendon is mobilized the *full length of the incision.* A second longitudinal incision is next made around the apex of the heel in the midline down to the periosteum This incision is connected with the first by subcutaneous dissection as deep as

possible (Fig 911), and a V shaped groove, an inch in length and sufficiently deep to receive the peroneal tendon is cut into the apex of os calcis. By means of a buttonhook, the peroneus longus tendon is then pulled around into this new sulcus, the foot and ankle being placed in the extreme plantar flexion. It is important that the plantar dissection be extended to permit the pull of the tendon in its passage across the heel to be as direct as possible.

After Treatment.—A well padded cast is applied from the toes to the knee maintaining the foot and ankle in full plantar flexion. The cast is removed at the end of three weeks and physical therapy and active exercise are instituted. Six weeks postoperatively, the patient is allowed to walk in a shoe with a heel of sufficient height to correspond to the remaining plantar flexion. Thereafter the heel is gradually lowered

Transference of Peroneus Longus Tendon for Paralysis of the Tibialis Posticus Muscle

This transplant is applicable only to those rare cases wherein there is an isolated paralysis of the tibialis posticus muscle with consequent invertor and adductor weakness and a valgus deformity

Technic (von Baeyer)—The peroneus longus tendon is exposed by a small lateral incision and severed at the point where the tendon passes beneath the cuboid bone. A second small incision is made over the medial side of the scaphoid bone. Through the first incision, the short *distal* end of the severed tendon is mobilized and by blunt dissection, passed across the sole of the foot to emerge in the second incision on the medial side of the foot. A lateral incision is then made over the lower third of the leg the proximal or longer portion of the peroneus longus tendon identified and retracted from its sheath. After the lower portion of the muscle fibers is freed, the end of the tendon is passed obliquely by blunt dissection between the posterior surface of the ankle and tendo achillis from above and laterally to the internal malleolus, thence to the incision over the scaphoid. The two presenting cut ends of the peroneal tendon are reunited at this point.

STABILIZATION OF THE FOOT AND ANKLE

Operations on the Osseous Structures

Albert, in 1878 first attempted to stabilize a paralytic equinus foot by curetting the articular surface of the ankle joint to obliterate the joint. With the same object in view von Lesser in 1879 resected the joint between the lateral malleolus and the talus. The first arthrodesis of the ankle was performed at the Hospital for Ruptured and Crippled in 1894

To Whitman, however must go credit for placing the principles embodied in stabilization of the foot upon a sound basis. In 1901 he reported his methd of astragalectomy for paralytic talipes calcaneus, pointing out the importance of posterior displacement of the foot when weakness of the triceps surae is a factor He also stated that arthrodesis of the ankle joint was of little value in the presence of lateral distortion. In such cases, the operation must include the subastragalar and midtarsal joints as well

In 1905 Nieny of Germany likewise performed an arthrodesis of the subastragalar joint for lateral instability In 1913 G G Davis, of Philadelphia, described a method of horizontal transverse section of the foot with backward displacement. To Davis, credit must also be given for popularizing stabilization

of the foot His method however, does not permit backward displacement of the foot to a material degree, in the course of time, other procedures have been developed which permit more posterior displacement of the foot and better correction of other deformities.

Hoke, in 1921, and Dunn, in 1922 first suggested removal of bone between the cuneiform bones distally and the body of the astragalus proximally, for the purpose of producing posterior displacement of the entire foot in relation to the leg and ankle joint.

Hoke's method combined subastragalar arthrodesis with resection re shaping and reimplantation of the head and neck of the astragalus, and with posterior displacement of the foot

In the method of stabilization described by Dunn, posterior displacement of the foot was accomplished by excision of the tarsal scaphoid and removal of a portion of the head and neck of the astragalus, the amount of the latter removed depending upon the degree of posterior displacement of the foot desired Actual shortening of the foot itself is slight, since only the articular cartilage of the calcaneocuboid joint is excised. Both Dunn and Hoke advocated reestablishment of muscle balance by tendon transposition when necessary Hoke also emphasized the necessity of correcting torsion of the tibia and knock knee deformity when present.

In 1923 Ryerson recognizing that calcaneocuboid fusion should be added to foot stabilization if the entire physiological unit involved in lateral deformities of the foot was to be stabilized described his technic of "triple arthrodesis." This is a rational procedure, since the lateral movements of the foot are functions of both the subastragalar and astragaloscaphoid joints. Fusion of the calcaneocuboid joint affords greater stability and less tendency to recurrence of deformity further, in severe cases of varus and valgus of the foot, it permits better correction. Practically all stabilizations of the foot now include arthrodesis of the calcaneocuboid joint.

In 1922, Steindler presented a method of panastragaloid arthrodesis, which is particularly adapted to stabilization of the flail ankle. Goldthwait had previously described a method of arthrodesis consisting of denudation of all joints, both supra and infra astragaloid with the exception of the astragaloscaphoid joint, while Sir Robert Jones had described a two-stage procedure for arthrodesis of all the joints above and below the astragalus. Steindler's method originally did not include fusion of the calcaneocuboid joint, though he has since included this joint. In his procedure, the astragalus was not completely removed and replaced after denudation as had been advised by Lorthior in 1911 and Albee in 1915

Numerous modifications of the above fundamental forms of stabilization and adjutant procedures have been devised some of which have stood the test of time and use, while others have been abandoned. The majority of these have been devised in an effort to produce an arthrorisis, or partial limitation of ankle joint motion. Chief among the procedures still in common use are the posterior bone block of Campbell, and the foot stabilization described by Lambrinudi both of which limit plantar flexion or 'foot drop' These and similar procedures are described in the following section

It is, of course, unnecessary here to delineate the evolution and history of foot stabilization Excellent discussions of this subject have been presented by Hart, Hallgrimsson and Schwartz.

Stabilization of the foot is indicated whenever deformity with or without instability of the foot, is accompanied by a laterally stable astragalus.

Foot stabilization is an orthopedic procedure of considerable refinement. No operation on the foot is so frequently performed which involves so many articular surfaces at one time. Hence an intimate knowledge of the normal structure and function of the foot is necessary Fundamentally the problem *of foot stabilization in paralysis is reduction of the number of joints which* the atrophied and weakened or even paralyzed muscles should control.

Measures which involve arthrodesis of the tarsal joints should not be undertaken until the patient reaches the age of nine or ten years, or preferably older Prior to this time the tarsal bones consist principally of cartilage there is relatively little cancellous bone to insure fusion. Further operations of such magnitude may be followed by considerable growth disturbance.

The incision employed will vary somewhat with the particular deformity present as well as with the experience and preference of the operator The most commonly employed incisions are either the anterolateral (preferred by Campbell), the Kocher, or the Ollier, or minor modifications of one of these (see Chapter IV) Some surgeons also employ a short medial exposure of the astragaloscaphoid joint in addition to one of the above approaches, feeling that this accessory incision reduces the operative time reduces the amount of retraction on the skin edges incident to the lateral approach (this being the most difficult of the three joints to approach from the lateral side, especially when there is a valgus deformity of the foot) and consequent tendency to necrosis of skin edges and permits a more accurate fitting of the joints. In the Hoke and Dunn types of arthrodesis, however little difficulty is encountered in complete and accurate removal of the proximal scaphoid or cuneiform articular surface since either the head and neck of the astragalus or the scaphoid or both have been removed. In the Ryerson type of ' triple arthrodesis,'' considerable difficulty may be encountered in excising all of the cartilage from the medial aspect of the astragaloscaphoid joint, unless the exposure extends far enough on the dorsolateral aspect of the tarsus, or an accessory medial incision is employed.

Stability of the astragalus in the ankle mortise is essential. Should one be in doubt as to the lateral stability of the ankle, anteroposterior roentgenograms are made of the ankle, with the foot in extreme varus and valgus comparing these, any lateral instability of the astragalus can be determined If instability is present arthrodesis of the ankle may be indicated in conjunction with stabilization of the foot. Failure to recognize this ankle instability preoperatively may result in instability of the foot on weight bearing and even in recurrence of the deformity despite a satisfactory stabilization of the foot.

Schwartz stresses the importance of preoperative roentgenographic analysis of the foot so that individual variations may be determined and the operation directed toward correction of the particular structural abnormalities which may be present. A paper tracing may be made of the lateral roentgenogram and the tracing divided into its tibioastragalar component, os calcis component, and the component comprising all the bones of the foot distal to the midtarsal joint these may then be reassembled with the foot in the desired position, and the size and shape of the wedges to be removed may be accurately determined. By this means the precision of the procedure is greatly increased

The operation must be carried out with the accuracy and care of a cabinet maker The resections in the different joints must be sufficiently wedge-shaped

to permit easy closure of the defect with close apposition of the bone surfaces, and with perfect alignment of the foot, especially in regard to the position of the heel or hindfoot The hindfoot is best placed exactly in the midline position, a mild valgus of the heel may not adversely affect the functional result, though a varus position of the heel will certainly do so! It is well to remember that the purpose of the postoperative cast is not correction of the position of the foot but only maintenance of the position obtained at operation

The details of the operation will vary somewhat with the nature of the deformity For example the details of a stabilization for a paralytic equinocavovarus deformity of the foot will differ materially from those of a stabilization in equinovalgus. Only by attention to these points will uniform, satisfactory results be obtained

In talipes equinocavovarus, bony hypertrophy of the dorsolateral aspect of the os calcis, the cuboid and the head and neck of the astragalus is present to a varying extent. The head of the astragalus lies in a position lateral to normal in relation to the median line of the foot, and the metatarsal shafts pitch medially downward and in some degree of rotation In simple equinus there is less fullness over the dorsolateral aspect of the tarsus, but a more noticeable overgrowth of the head and neck of the astragalus superiorly in the median line which causes a definite block to dorsiflexion even though the tendo achillis is lengthened In stabilizing a varus foot the head of the astragalus should be replaced slightly to the inner side of the median line of the foot whereas in an equinocavus foot deformity, the head of the astragalus is reduced in size and is implanted deeply on the anterior end of the os calcis in the median line

The structural pathology in talipes planovalgus is the opposite of that found in talipes equinocavovarus. The medial and plantar aspects of the head and neck of the astragalus and of the tarsal scaphoid present different degrees of enlargement. In marked cases, especially such as that seen in severe congenital flatfoot, an inferior subluxation or even plantar dislocation of the head of the astragalus is present. Abduction of the forefoot and dropping of the longitudinal arch of the foot are associated with this plantarflexion of the astragalus This being true the head of the astragalus must be raised from its deep bed on the inner side of the foot, and the anterior end of the os calcis shifted medially beneath the head and neck of the astragalus. To permit this shift, a considerable portion of the head and neck of the astragalus must be excised and a generous wedge removed from the medial aspect of the subastragalar joint. The valgus position of the os calcis must not be overcorrected however since the forefoot has a tendency to become supinated upon correction of the valgus of the hindfoot. This supination should be corrected at the time the valgus of the forefoot is corrected and the longitudinal arch of the foot is re-established If necessary the prominent navicular tuberosity is removed through a small medial incision. Miller recommends immobilization in plaster longer than usual *following* stabilizations, so that a firm fusion will be obtained before full unsupported weight bearing is begun.

As a rule, the muscle balance of the ankle and foot determines the necessary degree of posterior displacement of the foot. Forward transference of the fulcrum (the ankle) to a position nearer the center of the foot lengthens the posterior lever arm of the foot this is especially advantageous if the triceps surae group is weak Thus, when as much backward displacement of the foot as possible is desirable the method of Hoke or Dunn is used the latter opera

tion permits slightly more displacement than the former If the dorsiflexors and plantarflexors of the ankle are sufficiently strong Ryerson's triple arthrodesis may be performed

At the time of stabilization, the foot should be placed in correct relationship to the ankle joint without regard to associated deformities in the remainder of the extremity such as knock knee or tibial torsion. These should be corrected later at the site of the deformity in the tibia or femur otherwise, malalignment of the extremity may lead to recurrent deformity of the foot, despite stabilization.

In stabilizing the feet in adults, one should not attempt to change the weight bearing relationships materially, as the added strain on the structures and ligaments which are not strong enough to bear this will often result in disappointment for a few months after the operation. There is usually more swelling following operations on the feet in adults than in children and edema of the foot and leg after use may persist for several months after operation.

Marek and Schein have called attention to the possibility of aseptic necrosis of the body of the astragalus following foot stabilization and pan astragalar arthrodesis. This complication is apparently more prone to develop in adolescents and adults than in young children, and occurs most often after wide resection of the head and neck of the astragalus. If present aseptic necrosis may be detected roentgenographically as early as three or four weeks following operation In the average adolescent, revascularization is complete within six to nine months, and collapse of the body of the astragalus may be prevented by delaying resumption of weight bearing until this has been accomplished If premature weight bearing is allowed, the body of the astragalus will become compressed the ankle joint damaged and secondary degenerative changes will take place in the joint In this event, fusion of the ankle may ultimately be required for relief of pain and disability

According to Hoke a satisfactorily stabilized foot should present the following qualifications First it should look natural in shoes second, it should not turn laterally on the long axis of the foot when the patient is standing and walking third the use of a brace to maintain a natural or approximately natural position should not be necessary and fourth when bare the foot should present a natural appearance or at least no gross deformity

To these criteria Thompson has added the following The weight should be evenly distributed over the plantar surface during stance and gait the axis of the ankle joint should be well forward and at right angle to the long axis of the foot the patient should be able to control ankle-joint motion and should experience no pain. An artificial foot fulfills these requirements, and certainly a stabilized foot should be equally as good as an artificial one.

Crego and McCarroll have studied a series of 1 100 stabilizations of the foot for deformities incident to poliomyelitis. In the majority of cases, a triple arthrodesis was performed. Deformity recurred following 212, or approximately 20 per cent of these operations. Although associated deformities in another portion of the extremity and stabilization at too early an age were responsible in a number of cases, the factor most frequently encountered was muscle imbalance.

These authors suggest that, unless the muscles are completely paralyzed, the peroneal and anterior and posterior tibial tendons be transplanted to the midline posteriorly or anteriorly Their only exception to this rule is a cavus

deformity produced by paralysis of the intrinsic muscles of the foot while the long muscles remain normal. This viewpoint is slightly extreme, as less radical tendon transference generally may be carried out in conjunction with stabilization of the osseous structures to obtain sufficient muscle balance to prevent recurrence. As stated by Peabody (p 1302), *static deformities may be satisfactorily* corrected and maintained by fusion and blocking procedures without the danger of further deformity, correction of dynamic deformities cannot be maintained in a growing child by arthrodesis alone, regardless of its extent

Technic (Davis).—An incision two inches in length is made on the outer side of the foot, extending distally from the *posterior edge of the malleolus.* The peroneal tendons are retracted and with a chisel and periosteal elevator, the soft structures are raised from the bone anteriorly and posteriorly. A transverse horizontal section is made entirely through the tarsus from the junction of the os calcis and astragalus posteriorly to the anterior surface of *the cuneiform bones, the joints being disregarded.* The section passes through the subastragalar joint, cutting off parts of the os calcis and lower portion of the astragalus. The *upper portion of the cuboid, scaphoid* and *cuneiform bones* may also be included. These loose fragments may or may not be removed.

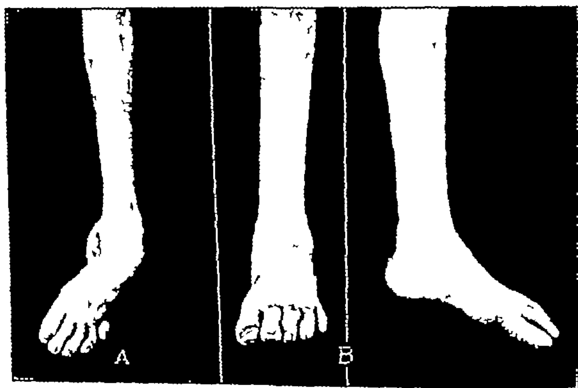


Fig 311.—*A* Pes equinovarus deformity *B* After triple arthrodesis and lengthening of tendo achillis.

An incision one inch in length is next *made on the inner side of the foot* below the internal malleolus and over the sustentaculum tali. The tendon of the tibialis *posticus is exposed, delivered from* the sheath, and retracted. The soft tissues having been freed from the bone anteriorly and posteriorly, the bone section is completed on the inner side. An effort is made to displace the *foot backward.* If this is unsuccessful, the soft tissues are *further* loosened until the foot may be displaced as far backward as desired. All loose pieces of cartilage or bone are removed *from the wound*

Davis often combined this procedure with tendon transference by implanting the peroneal tendons in the os calcis through an extension of the external incision proximally

After Treatment.—See p 1321

"Triple arthrodesis" is a term popularized by Ryerson to designate fusion of the calcaneocuboid, astragaloscaphoid and subastragalar joints. The technic of this operation as commonly employed by the author is as follows

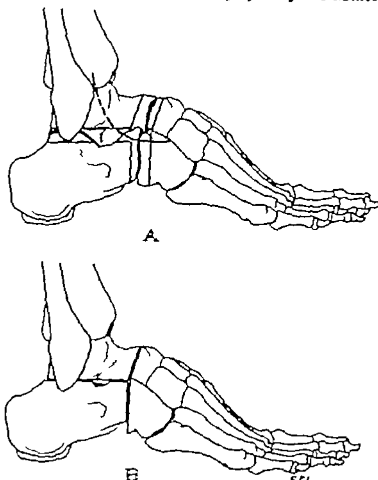


Fig. 918.—Triple arthrodesis, *A* Line of skin incision. Shaded area indicates amount of bone removed. *B* Completion of operation.

Technic.—The skin incision is begun just above and medial to the external malleolus and carried distally on the anterolateral aspect of the foot to the distal border of the cuboid bone. The extensor digitorum brevis muscle is exposed and detached at its origin on the os calcis or the muscle fibers are split longitudinally By subperiosteal dissection, the soft structures are stripped from the dorsal surface of the tarsal bones, the extensor muscles and tendons being retracted to the medial side of the foot With an osteotome, a section of bone is excised, consisting of the head and a varying portion of the neck of the astragalus and the contiguous articular surface of the scaphoid. The articular surfaces are then removed from between the os calcis and cuboid bones. In the presence of an extreme valgus deformity a larger section is removed from the astragalus, and the scaphoid bone is partially or wholly excised complete removal necessitates resection of the cartilage covering the proximal surface of the medial cuneiform bones. If there is a varus deformity of the foot a wedge-shaped section of bone is excised from the

midtarsal joints, its base being toward the lateral side of the foot. The raw osseous areas of the resected midtarsal region are then approximated in proper alignment. Through the same incision the soft structures are next stripped from the neck of the astragalus and os calcis, the ligaments divided, and the subastragalar joint is defined. A section of bone, including the cartilaginous surfaces, is then removed from the subastragalar joint. If the os calcis is inverted, the larger amount of bone is resected from the lateral side of the joint; if everted, from the medial side. After free dissection about the internal and external malleolus, the foot is displaced backward so that the burden of weight may fall nearer the center of the foot. *Osteogenesis is stimulated and fusion takes place more rapidly if the apposing bony surfaces are roughened with an osteotome and the space between is filled with particles of cancellous bone.* A more secure fixation of the midtarsal bones may be effected by catgut sutures inserted through holes drilled in the os calcis and cuboid bone, and *the astragalus and scaphoid respectively, or by stainless steel wires* (Caldwell) or staples (Burns). Finally the foot and ankle should be examined to determine whether the external contour of the foot and the weight bearing alignment are satisfactory. The foot should be in slight equinus or at a right angle, the arch should be symmetrical, and the weight bearing line should be *through the center of the astragalus.*

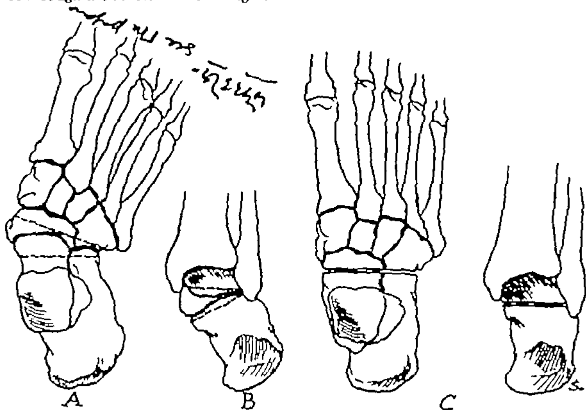


Fig. 916.—Triple arthrodesis and reconstruction for valgus deformity. *A* Wedge-shaped section of bone removed from midtarsal region, with base on medial side of foot. *B* Eversion of os calcis corrected by wedge-shaped resection of subastragalar joint. Shaded areas indicate amount of bone removed. *C* Operation completed.

After Treatment.—A boot cast is applied maintaining the corrected position, and a window is cut over the dorsum of the foot and ankle to allow for postoperative swelling. *The foot is held in an elevated position for several days to reduce the reaction to a minimum.* After three weeks the cast is removed, and, *if the relations of the bones are not accurate,* changes in posi

tion are adjusted by manual force. A walking boot cast is then worn for a period of four weeks. Eight weeks postoperatively an ankle brace is fitted, the joint limiting plantar or dorsiflexion, as indicated. Inner or outer T straps may be attached to maintain slight varus or valgus of the foot. The brace is rarely discarded before the lapse of six months.

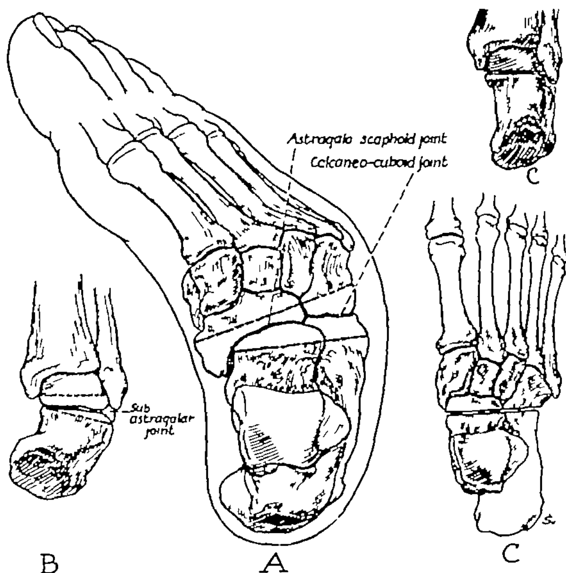


Fig. 917 —Triple arthrodesis and tarsal reconstruction for varus deformity. *A*, Wedge-shaped resection of bone removed from mid tarsus, including surfaces of mid-tarsal joints, with base of wedge on lateral side of foot. *B* Inversion of os calcis corrected by excision of bone from subastragalar joint, the major portion being removed from lateral side. *C* Operation completed.

Technic (Dunn).—Beginning one inch above and behind the external malleolus, an incision is curved across the lateral side of the foot to the third metatarsal bone. The soft structures on the dorsum of the tarsal bones are reflected medially. By means of an osteotome, the articular surfaces of the calcaneocuboid joint are resected, the head of the astragalus is excised just proximal to the articular surface and the proximal cartilage and dorsal surface of the cuneiform bones are next removed with the whole or a portion of the scaphoid bone. The interosseous ligament between the astragalus and os calcis and the external lateral ligament of the ankle are divided, and the foot is dislocated medially at the subastragalar and midtarsal joints. The

cartilaginous surfaces of the subastragalar joint are then resected Since the foot is now in three sections, sufficient bone may be removed to correct the deformity The forefoot is then displaced backward permitting the anterior aspect of the neck of the astragalus to rest in the cup-shaped depression prepared by removal of bone from the dorsal surface of the cuneiform bones, and apposition of the os calcis and cuboid To allow backward displacement of the foot at the subastragalar joint, a larger section of bone is removed from the inner side of the tarsus than from the calcaneocuboid joint. The calcaneocuboid wedge determines the degree of shortening of the foot, while the wedge including the scaphoid bone represents the shortening of the foot in addition to the amount of backward displacement at the subastragalar joint.

After Treatment.—See p 1321

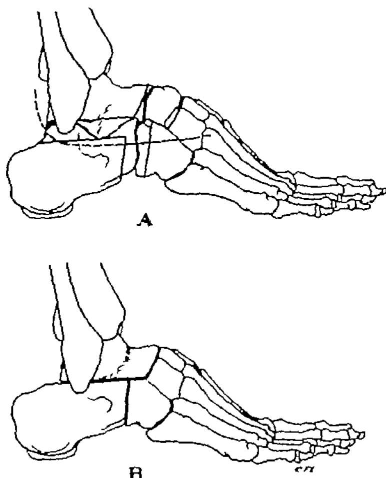


Fig. 918—Naughton Dunn arthrodesis. A, Line of skin incision. *Shaded area* illustrates bone resected to shorten and stabilize the foot. *B* Operation completed. The foot is displaced backward at the subastragalar joint. The head of the astragalus articulates with a cup in the cuneiform bones.

Technic (Hoke)—A skin incision is made from the lateral portion of the head of the astragalus downward and backward to a point below the end of the fibula in the interval between the tendons of the peroneus tertius and longus. The adipose tissue occupying the subastragaloid fossa is dissected superior surface of the neck of the astragalus is freed of soft tissue. The head of the astragalus is separated from the scaphoid by dividing the astragaloscaphoid ligament with a scalpel, beginning below and externally sweeping around the head, and ending medially A portion of the inferior surface of the body of the astragalus and adjacent surface of the os calcis is

next excised with an osteotome. The head and neck of the astragalus are severed from the body, divested of soft tissue attachments, removed, and preserved in a sterile towel. The cartilaginous surface of the scaphoid and the facets on the superior surface of the os calcis are then denuded with a small chisel.

After completion of these procedures, lateral or rotation deformities of the foot may be corrected and the os calcis shifted into satisfactory alignment, or if desired the foot may be displaced backward. The head of the astragalus is denuded of cartilage and replaced between the scaphoid and body of the astragalus, the position of the head depending upon the type and degree of the deformity. The foot is then brought into slight dorsiflexion.

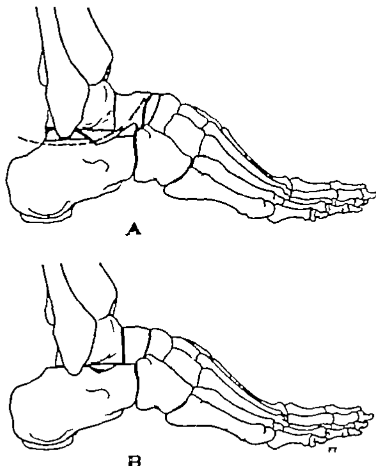


Fig. 919.—Hoke arthrodesis and tarsal reconstruction. *A* Line of skin incision. Shaded area is resected. *B* Operation completed. The reshaped head of the astragalus is replaced.

The above description is taken from Hoke's original paper. Kite, who was Hoke's associate for many years, now includes the calcaneocuboid joint in the *arthrodesis, and performs the procedure in the following order.* First, the sinus tarsi is delineated and the superolateral corner of the anterior articular surface of the os calcis is excised to facilitate exposure. The calcaneocuboid joint is then excised, appropriate wedges of bone being removed to correct any lateral deformity. The subastragalar articular surfaces, including that of the sustenaculum tali, are now removed. The superior surface of the head and neck of the astragalus is denuded with a knife, the neck of the astragalus is divided with an osteotome and the soft tissue attachments of the head and neck are severed with a scalpel and scissors. A large spoon curette is used to remove the

head of the astragalus thereafter, the posterior articular surface of the scaphoid bone is completely denuded of cartilage. In the presence of a club-foot deformity the plantar calcaneonavicular (spring) ligament is divided medially and inferiorly to permit better correction of the deformity in this portion of the foot. Kite also advocates 'fish-scaling' of the denuded articular surfaces of the respective joints to be arthrodesed. Following reshaping and reduction in size, the head and neck fragment of the astragalus is replaced in the defect in the desired position. Remaining bony fragments are utilized to fill any defect in the vicinity of the sinus tarsi.

After Treatment.—See p 1321

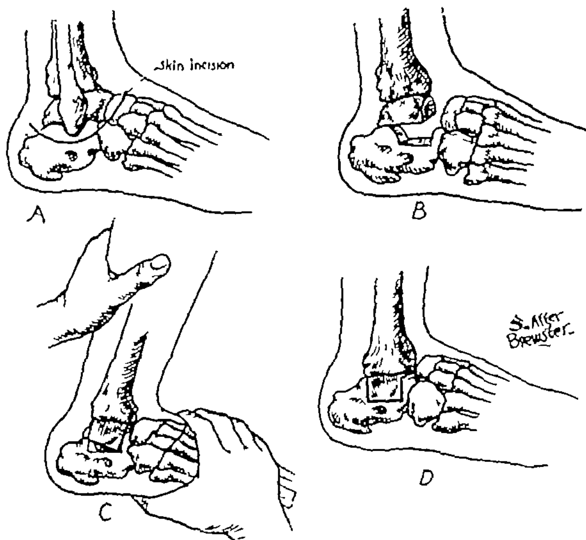


Fig 320—Brewster stabilization procedure for *flail foot.* *A* Line of skin incision. *B* After resection of subastragalar joint and head of astragalus, section of bone, corresponding in size to astragalus, is removed from superior *surface of os calcis.* *C* Anterior end of astragalus fitted into os calcis. Dotted line posteriorly indicates amount of bone to be removed from os calcis and astragalus. *D* Astragalus countersunk into *os calcis, thereby limiting the range of* dorsal and plantar flexion. (Redrawn from *Brewster* A. H. New England J Med. 209: 71 1932.)

Brewster has described a stabilization procedure for flail foot wherein lateral stability as well as limitation of plantar and dorsal flexion is secured by countersinking of the astragalus into the os calcis and fusion of the scaphoid and astragalus.

Technic (Brewster)—A curved incision is made on the lateral side of the foot, beginning at the head of the astragalus and continuing below the ex

ternal malleolus to the posterior superior surface of the os calcis. The peroneal tendons are retracted, and both the anterior and posterior portions of the subastragalar joint are divested of soft tissue and exposed. With an osteotome, the cartilaginous surfaces of the subastragalar joint are resected in a plane parallel to the plantar surface of the foot. The head and neck of the astragalus are severed at a right angle to the sole of the foot, together with a portion of the cartilage on the superior surface of the body of the astragalus, and removed. Similarly the posterior surface of the astragalus is excised level with the posterior surface of the tibia. The foot is then displaced backward on the leg. At a point corresponding to the anterior and posterior surfaces of the astragalus, a chisel is driven into the os calcis at a right angle to the plantar surface of the foot, and a section of bone is removed from side to side. The astragalus must be countersunk in the os calcis to a sufficient depth to permit the tarsus to impinge upon the tibia both anteriorly and posteriorly and thus limit plantar and dorsal flexion to the desired degree. The astragalus is then reduced into this cavity. The posterior articular surface of the scaphoid is denuded and approximated to the anterior surface of the body of the astragalus.

After Treatment.—See page 1340

Triple Arthrodesis and Reconstruction for Calcaneocavus Deformity

In order to minimize the extent of surgery on the bones and reduce the total shortening of the foot, the calcaneocavus deformity should first be corrected in so far as possible by operations on the soft structures, such as subcutaneous tenotomy, even plantar fasciotomy or the Steindler stripping operation. Any stabilization operation for paralytic calcaneocavus deformity with or *without associated varus or valgus, should displace the foot posteriorly* as much as possible. For this reason either the Hoke or Naughton Dunn type of stabilization supplemented by transference of available muscle power into the tendo achillis and os calcis, is most suitable. The posterior displacement of the foot increases the lever arm of the calcaneum, thus less muscle strength is required for lifting the heel. For example if backward displacement of the foot is combined *with an implantation of the peronei into the os* calcis, the increased lever arm facilitates the function of these muscles to such a degree that the anteroposterior balance of the foot is improved and not infrequently a considerable amount of lifting power upon the os calcis is displayed. The effect is apparent even though both peronei have only a small portion of the contractile power of the triceps surae group.

Technic.—*Subcutaneous tenotomy or plantar fasciotomy* (p. 1297) or the Steindler stripping operation (p. 1298) are carried out to release the contracted soft tissue structures which bridge the longitudinal arch from the os calcis forward. The cavus deformity is then forcefully corrected as much as possible.

The calcaneocuboid, astragaloscaphoid and subastragalar joints are exposed *by the incision employed for triple* arthrodesis (p. 1320). With an osteotome, a wedge shaped or cuneiform section of bone, its base on the dorsum of the foot, is removed from the astragaloscaphoid and calcaneocuboid joints. The wedge should be of sufficient size to correct the remaining cavus deformity after partial correction is secured by severance of the contracted plantar soft tissues. The forefoot is then placed in dorsiflexion and the raw surfaces approximated to determine whether any cavus deformity persists. If correction

is satisfactory the subastragalar joint is next exposed a wedge shaped section of bone with its base posteriorly is removed from this joint and the calcaneus deformity or angulation of the os calcis is corrected Close approximation of all osseous surfaces with the foot in satisfactory alignment is assured before closure of the wound

After Treatment.—Immediately after operation a plaster cast is applied with the foot in moderate equinus and the knee slightly flexed In order to stretch the plantar structures as much as possible firm pressure is applied to the sole of the foot while the plaster is setting

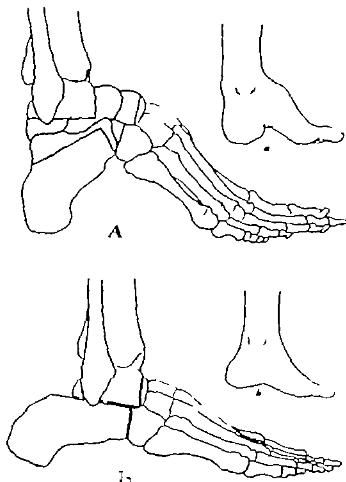


Fig 321.—Triple arthrodesis and reconstruction for calcaneocavus deformity *A*, Amount of bone resected. *B* Completion of operation. Note backward displacement of foot at subastragalar joint.

Miller has pointed out the value of postoperative manipulation following *stabilization for calcaneus deformity* at the end of five weeks, *the cast is removed* for a refining manipulation of the foot. Firm pressure is directed upward on the sole of the foot and upward and backward on the heel flattening the arch of the foot and thrusting the os calcis upward and backward There after a short cast is applied *from* the toes to the knee the same forces of pressure being exerted during the setting of the cast as were applied during the manipulation.

Jones Operation for Calcaneovalgus

The Jones operation for calcaneovalgus has in our opinion been supplanted by foot stabilization and tendon transference as described above or

by panastragalar arthrodesis described below For the sake of completeness, however the technic is described

Technic.—(First Stage.) Through a three- or four inch incision along the medial side of the foot the plantar fascia is divided and the soft tissues are stripped from the mid tarsal region on both the plantar and dorsal aspects.



Fig. 922.—Calcaneocavus deformity before and after tarsal reconstruction and arthrodesis.



Fig. 923.—Fixed cavus deformity treated by Steindler stripping operation, lengthening of tendo achillis, and tarsal reconstruction and arthrodesis.

A cuneiform section of bone, its base toward the dorsum of the foot, is removed from the mid tarsal area any associated valgus or varus deformity is corrected by making the section slightly wider on the inner side, as may be re-

quired. The cavus deformity is obliterated by dorsiflexion of the forefoot, which is now bandaged to the tibia By this procedure, the calcaneus deformity apparently is increased. After three to four weeks the second stage is carried out.

(Second Stage) A longitudinal incision is made over the tendo achillis to the posterior surfaces of the ankle and subastragalar joints. Sufficient bone is removed from these surfaces to correct the calcaneus deformity and place the foot in slight plantar flexion. Both the ankle and subastragalar joints are fused.

After Treatment.—See Triple Arthrodesis (p 1321)

Panastragalar Arthrodesis

Panastragalar arthrodesis is the surgical fusion of the tibioastragalar, astragaloscaphoid, subastragalar and calcaneocuboid joints. This procedure in effect is similar to that of the Jones operation for calcaneovalgus The operation is indicated in patients who have calcaneus or equinus deformities in combination with lateral instability of the foot and in whom the leg muscles are not sufficiently strong to control the foot and ankle if only the foot itself is stabilized. Also the procedure furnishes a means of stabilizing the knee in the presence of instability from paralysis of the quadriceps muscles. Braces which have been worn for instability often may be discarded following the operation, and the gait becomes easier, smoother and less fatiguing

Steindler recommends a one-stage operation (see below) while Liebolt and King advise stabilization of the foot as one stage of the operation and fusion of the ankle as a second stage They advocate a two-stage procedure because of the difficulty which may be encountered in attempting to maintain the desired degree of equinus in the ankle and the proper weight bearing position On the other hand if the foot has first been stabilized in proper weight bearing position the proper degree of equinus at the ankle is obtained with relative ease at the second stage in the event postoperative roentgenograms do not reveal the desired degree of equinus, the cast may be wedged to correct any discrepancy

Before a panastragalar arthrodesis is carried out one must be certain that the knee allows full extension or even a few degrees of hyperextension and there must be some mechanism to protect the knee against recurvatum usually functioning hamstrings, or occasionally in the absence of functioning hamstrings, adequate gastrocnemius function

The foot should be stabilized in a good weight bearing position, preferably in neutral position though a slight amount of valgus is preferable to any degree of varus of the heel The ankle should be fused in equinus, the degree varying according to the sex of the patient and the condition for which operation is performed. Liebolt and King advise a position of 95 degrees for a man whose shoe heel height is about three fourths inch, while for a woman whose ordinary shoe heel height is approximately two and one-fourth inches an equinus of 105 degrees is satisfactory One may estimate the most desirable degree of equinus by determining the height of the heel which the patient ordinarily wears or would wear 5 degrees of equinus being allowed for each three-fourth inch of heel height. If however the procedure has been performed to stabilize the knee because of quadriceps weakness, the heel height should be just less than enough to compensate for the degree of equinus present in the ankle in order that the knee will be stabilized in full extension or even slight hyperextension when weight is borne on the affected leg The

desired position for fusion of the ankle in this particular condition is not necessarily the same as that for fusion in traumatic arthritis or other entities associated with a normal foot or normal extremity

To compensate for the loss of midtarsal motion an equinus of approximately 5 more degrees is indicated if the foot has been stabilized than if an ankle fusion alone is done (see p 994) The proper degree of equinus may be easily determined preoperatively by a lateral roentgenogram made with the patient standing while wearing a shoe with a heel of the desired height. In drop foot or calcaneus with associated instability of the knee, one may determine preoperatively whether foot stabilization and ankle fusion will successfully stabilize the knee by applying a short leg walking cast with the foot in approximately 100 degrees of equinus If this stabilizes the knee one can *then be certain that the knee will be stable following fusion of the ankle in the proper degree of equinus.*

Technic (Steindler).—Though the Kocher approach affords excellent exposure an anterolateral incision just anterior to the tip of the external malleolus is preferred in that the inferior ligaments of the astragalus should not be disturbed more than necessary in order to conserve the blood supply to the astragalus. (In the procedures described by Lorthior and Albee the astragalus is temporarily removed in some cases however, this resulted in an aseptic necrosis of the astragalus particularly in adults.) The extensors of the toes are retracted medially the lateral ligaments of the ankle are divided, and the joints opened by extreme supination and adduction of the foot, as in the Whitman astragalectomy To provide adequate exposure of the ankle joints as well as the subastragalar joint, the astragalus is mobilized by division of all the ligaments to the neighboring bones except the inferior ligament. The cartilage of the tibia and fibula is denuded and that of the body of the astragalus is then removed. Following denudation of the ankle joint, the astragalus is pulled upward and the subastragalar joint including the facet of the sustentaculum tali is denuded of cartilage In the presence of lateral deformity correction may be accomplished by removal of the subastragalar and midtarsal joints

Technic (Liebolt).—Stage one *The foot is stabilized by the method described by Hoke (see p 1323)*

Stage two Fusion of the ankle. The ankle joint is approached by a five-inch anterior incision the transverse crural and cruciate ligaments being divided. The external hallux longus and anterior tibial tendons, together with the dorsalis pedis artery vein and deep peroneal nerve, are retracted medially and the extensor digitorum longus tendons laterally The anterior lateral malleolar artery and vein are divided and ligated. The periosteum over the tibial diaphysis is next incised though one should avoid stripping the periosteum over the epiphyseal cartilage The articular cartilage is then removed *together with sufficient bone to correct the deformity* or to place the foot in the desired position. With a curved osteotome, opposing surfaces are fish scaled to insure good bony contact between the tibia and the astragalus. Through the same incision, bone is removed from the lower tibial metaphysis well above the epiphyseal plate and small chips of this bone are wedged into the ankle joint, especially between the astragalus and the malleoli, to eliminate the space created by removal of the cartilage and provide firm bony contact. A few bone chips may also be placed over the anterior aspect of the ankle

joint. If the patient is still in the period of growth, one should exert every effort to prevent damage to the distal tibial epiphyseal plate during the entire procedure

After Treatment.—A cast is applied extending to the midthigh, immobilizing the knee in moderate flexion and the ankle in the estimated proper degree of equinus. The front part of the foot should be in the maximum degree of dorsiflexion on the rear part, since this is its weight bearing position Postoperative roentgenograms are made and the degree of equinus determined by two lines one drawn down the midshaft of the tibia and the other drawn from the base of the head of the first metatarsal to the base of the os calcis. If the degree of equinus is not exactly as desired, the plaster should be wedged within a few days after operation At the end of six weeks, a new cast is applied which extends only to the knee, and weight bearing is instituted. If roentgenograms made six weeks later reveal solid fusion of the ankle, the patient may be allowed to begin weight bearing in a shoe with a heel of adequate height.

Anterior Tarsal Wedge Osteotomy for Cavus

This procedure is indicated in cavus deformity of the foot without varus of the os calcis or gross muscle imbalance but wherein there may be contracture of the plantar structures and clawing of the toes. Motion in the midtarsal and subastragalar joints is preserved yet the cavus deformity is satisfactorily corrected. If varus of the heel is associated the cavovarus deformity of the foot must be corrected by triple arthrodesis (p 1320)

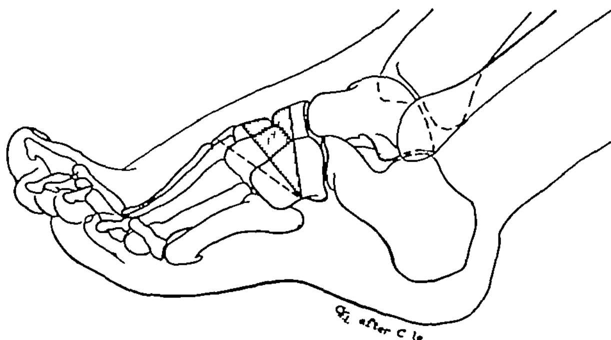


Fig. 924.—Cole technic for correction of cavus deformity of foot by anterior wedge-osteotomy of tarsus. Midtarsal joints are preserved. Dotted line shows distal limits of this operation. (From Cole, W. H. J Bone & Joint Surg. 22 895 1940)

Technic (Cole)—A dorsal longitudinal incision is made beginning just proximal to the midtarsal joint and extending distally to the level of the middle of the metatarsal shafts. The extensor tendons are separated the plane of separation usually lying between the extensor tendons to the third and fourth toes. The periosteum is incised longitudinally and is elevated medially

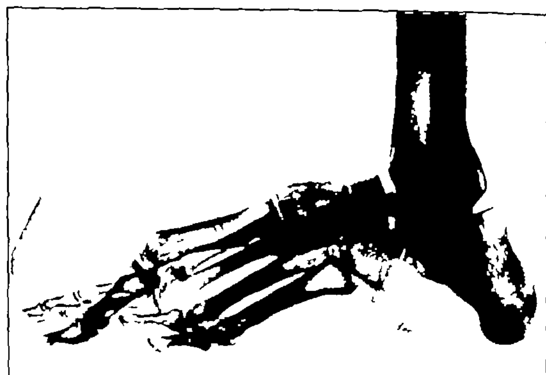


Fig. 926.—Whitman astragalectomy twenty-seven years postoperatively. Patient has excellent function. Played football, basketball, and baseball in college.



Fig. 927.—Whitman astragalectomy followed by solid fusion of tibia to os calcis. Disability no greater than that incident to fusion of the ankle.

of the leg This procedure is supplemented if necessary by careful bracing to prevent excess deformity of the foot and at some later time by a stabilization of the foot after the method of Hoke or Dunn. If indicated, the stabilization is supplemented by fusion of the ankle (see p 994) This is a more conservative plan and avoids imposing the shortening of an astragalus upon an extremity already weakened and frequently shortened by the residual paralysis.

Technic (Whitman and Thompson).—The astragalus is exposed through a long curved lateral Kocher incision (though Campbell preferred the anterolateral approach) and the peroneal tendons are divided The external lateral ligament of the ankle is incised and the foot is turned medially, thus permitting easy delivery of the astragalus The astragalus is excised preferably in toto no bony fragments being allowed to remain The ligaments are stripped from both malleoli and the lower half inch of the tibia that the foot may be easily displaced backward. The cartilage of the articular surfaces of both malleoli is removed the malleoli are reshaped on the inner surfaces to fit the new articulation and small areas are denuded on the inner and outer surfaces of the extreme anterior portion of the os calcis to conform to the raw surfaces of the malleoli. After the foot is displaced backward adequately the medial malleolus will lie over the tarsal scaphoid and the lateral malleolus will cover the calcaneocuboid joint To accomplish this the foot must be rotated externaly beneath the leg often to 30 or 40 degrees since the foot must be aligned with the ankle mortise rather than with the patella Thus the new axis of motion will extend between the two malleoli at a right angle to the long axis of the foot.

If the tibialis anticus is active it must either be released by excision of a long portion of its tendon or must be transposed

The peroneal tendons are sutured Evans and Steindler mention that the peroneal tendons may be inserted into the tendo achillis provided their muscles are active Thompson, however has found that any power which remains in the tibialis anticus or posticus or in the tendo achillis will almost surely produce a varus or equinus deformity

After Treatment.—The first cast, which extends above the knee with the knee in flexion, is applied with the foot displaced well backward, and in marked equinus and valgus. Any attempt to correct external rotation will produce a varus deformity

The cast is changed at the end of two to three weeks, the position of the foot is checked and if necessary minor modifications in position are made A snugly fitting cast is applied to just below the knee with the foot still in equinus, slight valgus, and external rotation commensurate with torsion of the tibia A few weeks later the heel of the cast is built up with cork or a rubber heel and the patient is allowed to bear weight on the extremity The cast is removed at the end of twelve weeks following operation, and a shoe is fitted The heel of the shoe is raised from one to one and one-half inches and an outer wedge is applied if there has been or is, the slightest tendency toward varus. If necessary a short double bar brace with a calcaneus ankle stop and an outside T strap to maintain the foot in valgus is temporarily applied. The patient is *not* allowed to walk barefoot for at least a year following operation.

If the patient cannot compensate for the external tibial torsion by internal rotation of the entire extremity, a tibial rotation osteotomy may be done at a later date.

Limitation of dorsiflexion at 100 degrees in a boy and at 110 degrees in a girl is considered ideal by Thompson though a fixed equinus of 120 degrees will give a strong foot and an excellent gait. A moderate equinus aids materially *in compensating for the shortening of the paralyzed extremity*, which is often considerable A lift under the heel of the shoe will distribute the body weight to the entire foot.

Anterior Bone Block for Paralytic Pes Calcaneus

The anterior bone block for paralytic pes calcaneus was first employed by Putti. The operation is similar in principle to the Campbell posterior bone block for drop foot, the obstruction, however is so placed as to prevent dorsiflexion of the foot. On the whole this procedure has proved unsatisfactory If muscle power is inadequate to restore adequate pushoff ' following tendon transference into the tendo achillis accompanied by stabilization with posterior displacement of the foot it is our policy at present to perform a pantalar arthrodesis

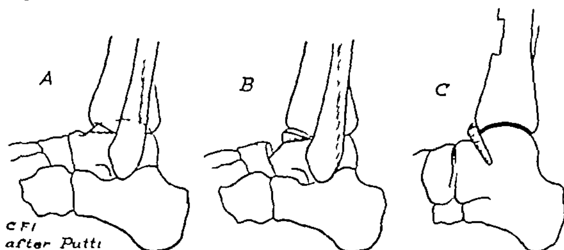


Fig. 922.—Putti anterior bone block for paralytic pes calcaneus. Technic II. *A*, Osteotome driven into articular surface of astragalu along dotted line and pried upward. *B* Defect filled with small fragment of bone from neck of astragalus, thereby forming a small bony abutment which impinges upon the tibia upon dorsiflexion. Technic I *C* Anterior bone block formed by small tibial peg.

Technic (Putti) —A longitudinal incision is made in the midline of the ankle joint, the extensor muscles are reflected medially and laterally and the ankle joint and anterior surface of the body of the astragalus exposed. The block may be formed by two methods (1) Through a separate incision, a small rectangular cortical graft is removed from the tibia. An osteotome is then driven into *the anterior superior surface* of the body of the astragalus transversely creating a cleft. The gap thus created is filled with the tibial graft, forming an anterior abutment which impinges upon the tibia on dorsiflexion beyond the desired degree. (2) An osteotome is driven transversely into the body of the astragalus anteriorly and the segment of bone above the osteotome is pried upward to impinge upon the anterior portion of the articular surface of the tibia. The wedge-shaped gap in the body of the astragalus is filled with chips from the neck of the same bone.

Campbell employed a somewhat similar technic After triple arthrodesis, the superior surface of the neck and anterior surface of the body of the astragalus are denuded and roughened. One large fragment of boné removed

from the tarsus is freed of cartilage and so placed in contact with the denuded area on the astragalus as to check dorsiflexion beyond 90 degrees after union of the bone block.

After Treatment.—The foot is maintained in slight plantar flexion for three or four months before unprotected weight bearing or active use of the foot and ankle is allowed

Lambrinudi has devised an operation for pes calcaneus, or "drop heel," wherein the ankle joint is allowed to lock in full dorsiflexion and the calcaneus deformity is corrected in the subastragalar joint. He reports cases which have been followed ten to twelve years without the development of subsequent degenerative arthritic changes or disturbances of growth The technic is somewhat similar to that employed for drop foot (see p 1343) with the exception of the shape and location of bone wedges removed. Following operation the foot is immobilized in complete equinus.



Fig. 929—Anterior bone block and tripl arthrodesis for paralytic calcaneus deformity

We have had no personal experience with this method since it has been felt that the patient would not be relieved of the calcaneal limp and since pushoff is not restored Further as in Lambrinudi s procedure for drop foot meticulous preoperative planning is necessary and the operation itself must be carried out with precision.

Bone Block Operations for Paralytic Equinus (Drop Foot)

Paralytic drop foot is characterized by paralysis of the anterior group of muscles with consequent inability to dorsiflex the foot actively Fre-

quently, the tendo achillis is contracted preventing even passive dorsiflexion. This status is not to be confused with fixed equinus deformities unassociated with paralysis, wherein contracture of the tendo achillis prevents normal action of active dorsiflexion of the foot and ankle.

Tarsal arthrodeses are designed to control lateral motion of the foot, and do not alter the degree of plantar or dorsiflexion of the ankle. In 1919 Campbell devised and reported locally an operation for correction of drop foot and in 1923 analyzed the results of twenty-three cases. This procedure evolved from principles established by an operation described by Campbell in 1917 for genu recurvatum wherein the deformity was corrected by utilization of the patella as a bone block.

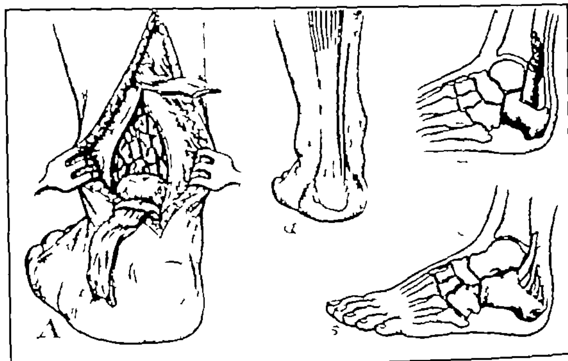


Fig. 930.—Campbell bone block for paralytic equinus (drop foot). a, Line of incision. A, Operation completed, showing large block of bone with numerous small chips pyramided above. B, Relation of block to subastragalar and ankle joints and to posterior surface of tibia. C, Posterior surface of joint exposed by retraction or Z-plastic division of tendo achillis. Bone block alone performed by reflection of bone forward and upward from superior surface of os calcis.

The technic of bone block for drop foot consists of transplantation of cavernous or spongy bone into the upper surface of the os calcis in close proximity to the ankle joint. This new bone fuses to the os calcis and forms an abutment which impinges upon the posterior and inferior surfaces of the tibia, limiting plantar flexion. In 1921 Toupet independently employed the same principle in an operation for drop foot, removing a graft from the tibia to form the block.

The bone block procedure is usually combined with triple arthrodesis; thus, the foot is stabilized as to lateral motion and sufficient motion is conserved in the ankle for satisfactory function.

Technic (Campbell).—The skin is incised along the inner border of the tendo achillis from the superior aspect of the tuberosity of the os calcis upward in a straight line for a distance of three or four inches. The tendo

achillis, if contracted, is lengthened by the Z-plastic method, but otherwise is retracted laterally Another straight incision is next made in the midline to the posterior surface of the ankle joint, and the tendon of the flexor hallucis longus muscle is retracted medially With a heavy periosteal elevator, a pyramidal space is cleared, exposing the posterior surface of the tibia ankle joint, subastragalar joint, and the superior surface of the os calcis. The foot is then dorsiflexed bringing into view the posterior surface of the astragalus. This portion of the astragalus is resected, and immediately beneath this resected area a wedge shaped cavity is excavated on the superior surface of the os calcis. Great care must be exercised to avoid denuding the posterior surface of the tibia otherwise, the bone block may adhere to this denuded surface leading to fusion of the ankle joint Since usually the forefoot must be stabilized by triple arthrodesis (p 1320) the bone thus removed is utilized for transplantation The fragments are denuded of cartilage and the largest



Fig. 931.—End result eighteen years after bone block for paralytic drop foot (Campbell)

which generally is the head of the astragalus or the scaphoid bone, is inserted into the cavity prepared on the superior surface of the calcaneus in *close apposition* to the posterior surface of the ankle joint. Small particles are then arranged in pyramidal shape around and above the wedge. The cartilage removed is placed in mosaic fashion over the posterior, inner and outer *aspects* of the pyramid to prevent adhesions to surrounding structures. The utilization of bone from the forefoot, however is by no means essential, *as* the results are equally good when cancellous bone is obtained elsewhere without *cartilage*. The soft tissues are sutured snugly to retain the transplants in situ. The tendo achillis, if severed, is united and the fascia and skin are closed.

When the forefoot has been previously stabilized the above technic may be modified by reflecting bone forward and upward *from* the superior surface of the os calcis or the cavity created by resection of the portion of the astragalus and excavation on the superior surface of the *os calcis* may be filled with bone from

any part of the skeleton Transplants of cancellous bone from the femur when the deformity is associated with genu valgum, and from the ilium in transference of the crest for flexion contractures of the hip have proved efficient.

After Treatment.—Immobilization is effected by a boot cast, the foot being held at a right angle. The position of the foot must be exact, that motion may be checked slightly below 90 degrees. *If the foot is immobilized*



Fig 932.—Campbell posterior bone block. *A* Stabilization and posterior bone block i childhood. Note that bony abutment impinges upon inferior as well as posterior surface of tibia. *B* Same foot 17 years after operation. Block is larger than necessary Result excellent.



Fig. 933.—Before and after Campbell bone block operations.

in dorsiflexion, a calcaneus deformity will follow causing the patient to bear weight on his heel, or if in plantar flexion, the block will not be adequate and the drop foot will partially recur If the foot is maintained at 90 degrees, there is always an increase in plantar flexion of 15 to 25 degrees, providing an excellent range of motion for walking

A window is cut in the cast over the dorsum of the foot and ankle to allow for swelling At the end of three weeks, a walking boot cast is applied and weight bearing is allowed one week thereafter Eight weeks postoperatively, a limited motion ankle brace is fitted to be worn for six months to one year

In no case have the grafts and transplants failed to unite Because of errors in technic, the block has been inadequate in a few cases, allowing the foot to drop into moderate equinus instead of checking motion at a slight equinus. Again motion of the ankle has occasionally been completely limited On the whole however, results from this procedure have been excellent, except in a few adults, arthritic changes have not developed in the ankle, nor have patients experienced pain either in the ankle or at the site of contact between the tibia and the block.

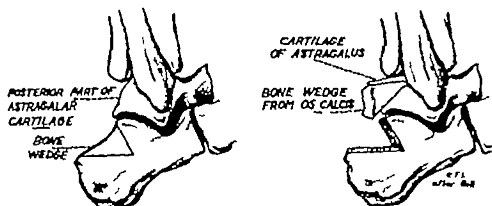


Fig. [illegible].—Gill technic for posterior bone block for paralytic drop foot. (Redrawn from Gill, A. B : J Bone & Joint Surg. 15: 166 1933)

Carrell reports satisfactory results i.e., painless ankle motion and a block of plantar flexion not exceeding 120 degrees in 110 of a group of 140 bone blocks for drop foot. A deficient or inaccurately placed block was responsible for poor function in ten of the thirty failures. In these cases, the block was inserted through an anterior rather than through a separate posterior incision. In ten cases there was forward displacement of the astragalus and block here again, the placing of the block through an anterior incision in part accounted for the instability since by this procedure the lateral portion of the ligament between the fibula and astragalus is incised The *remaining* failures were ascribed to an overactive tendo achillis with an inefficient block eventually, the constant pull opened the astragalotibial articulation, forming a *hinge joint* Carrell has found that in the presence of a weakened triceps surae, a small intra-articular or inferior block beneath the posterior extremity of the tibia is satisfactory but when the pull of the tendo achillis tendon is strong a block combining an inferior and posterior contact *against the tibia* as described above, is more effective. Of thirty two bone block operations, Steindler obtained satisfactory results following twenty seven.

Gill has modified the Campbell operation by *forming a cleft in the posterior* superior surface of the astragalus and filling this cleft with a wedge-shaped block of bone which impinges on the posterior articular surface of the tibia thereby preventing drop foot. The operation may or may not be combined with stabilization of the tarsal joints. The principal advantage claimed for the procedure is its simplicity

Technic (Gill).—Through a longitudinal skin incision, the tendo achillis is divided in a Z-plastic manner. After exposure of the ankle joint and top of the os calcis, the foot is dorsiflexed to the limit, bringing into view the posterior articular surface of the astragalus. With a broad, thin osteotome, the cartilage and a thin portion of the astragalus are lifted up from behind and approximated to the posterior lip of the tibia. The angle of the wedge-shaped space thus formed lies beneath the cartilage in front of the posterior lip of the tibia. A segment of bone of corresponding shape is then removed from the upper aspect of the os calcis and driven firmly into the space beneath the superior portion of the astragalus, maintaining the foot in dorsiflexion. The tendo achillis and the wound are sutured in the usual manner.

After Treatment.—The foot is immobilized in the position of slight dorsiflexion by means of a plaster cast and so maintained for a period of three months.



Fig. 935.—Bone block of Inclan, which combines the principles of the Campbell and Gill technics. (Courtesy of Dr. Alberto Inclan.)

Inclan combines the principles of the Campbell and Gill technics, obtaining the block by elevation of the posterior aspect of the articular surface of the astragalus. This osteocartilaginous flap is maintained in position by the head of the astragalus, which has been previously fashioned in the shape of a cock's comb. The block is denuded to present a double raw surface for contact with the back of the astragalus and superior surface of the calcaneus. The posterior portion of the block consists of the cartilaginous articular area of the head of the astragalus, providing a smooth gliding surface for the tendons. The block thus functions to limit motion by contact with both the inferior and posterior articular surfaces of the tibia.

In 1927 Lambrinudi reported a method for correcting paralytic drop foot in conjunction with stabilization. The procedure is designed to utilize the natural bony obstruction of the posterior tuberosity of the astragalus in such a way that dropping of the foot beyond a desired degree is not allowed. This operation controls the foot drop by correcting the equinus deformity in

the subastragalar joint and stabilizing the foot in a functional position in relation to the astragalus, the latter being locked in complete equinus within the ankle mortise

The procedure is indicated for the correction of a drop foot or of an equinus deformity when the dorsiflexor and peroneal groups are so weakened or paralyzed that transference to the midline of the foot to permit active dorsiflexion is not practicable It may also be used for a flail or dangle foot though in this instance a panastragalar arthrodesis may be preferable The operation may not be indicated in the presence of extreme shortening of the leg wherein the equinus deformity, with a shoe elevation serves to compensate for the shortening or if a mild equinus position of foot from contracture of the tendo achillis provides stability to the knee when the quadriceps femoris is weak or paralyzed. In a varus deformity incident to an active tibialis posticus, there is no dependable method of transferring the tibialis posticus anteriorly into the dorsum of the foot unless one desires to transplant the tendon posteriorly into the tendo achillis it should be inactivated by excision. Before undertaking the Lambrinudi procedure one should be certain that the ankle mortise is perfectly stable If lateral instability is present, stabilization of both the ankle and foot by a panastragalar arthrodesis would afford better function of the foot.

As suggested by Fitzgerald and Seddon, the procedure is of value in drop foot deformities from other causes such as hemiplegia permanent peroneal nerve injury as well as following traumatic or thermal destruction of the dorsiflexor and peroneal muscles. They also suggest that it may be of use in an old, imperfectly corrected clubfoot wherein dorsiflexion is never complete despite lengthening of the tendo achillis and posterior capsulotomy because of excessive breadth of the anterior portion of the superior articular surface of the astragalus When the Lambrinudi operation is so utilized, the remainder of the foot is brought up to the astragalus the latter being undisturbed.

It must be emphasized that if a satisfactory result is to be obtained with this procedure, meticulous attention to preoperative planning and to operative technic is necessary

Technic (Lambrinudi)—With the foot and ankle in extreme plantar flexion a lateral roentgenogram is made and the film is traced. The outlines of the os calcis and the remainder of the foot, excluding the astragalus, are cut out thus, the tracing is in three pieces. From this, one may determine with accuracy before operation the exact amount of bone to be removed from the astragalus to obtain the proper position of the foot. A position of 95 to 100 degrees' equinus is preferable unless excess shortening of the extremity makes more equinus desirable.

The tarsus is exposed through a long lateral curved Kocher incision. The peroneal tendons are sectioned in a Z-plastic fashion, the astragaloscaphoid and calcaneocuboid joints opened, and the interosseous and external lateral ligaments of the ankle are divided, permitting complete medial dislocation of the tarsus at the subastragalar joint. Its size having been determined preoperatively the wedge of bone is removed from the *inferior* surface of the neck and body of the astragalus for this purpose the use of a small handsaw permits greater accuracy and precision than the use of a chisel or osteotome The cartilage and bone of the superior surface of the os calcis are removed to form a plane parallel with the horizontal axis of the foot. A notch is next made

from side to side horizontally in the inferior portion of the posterior surface of the scaphoid, and the calcaneocuboid joint is denuded of sufficient bone to correct any lateral deformity. The sharp anterior margin of the remaining portion of the astragalus is firmly wedged into the prepared notch in the scaphoid and the os calcis and astragalus are approximated. Care is taken to place the 'beak' well medially in the notch in the scaphoid, otherwise, the foot will not be restored to a satisfactory relationship to the astragalus and the ankle mortise. Obviously no attempt should be made to compensate for a torsion of the tibia by altering the position of the foot.

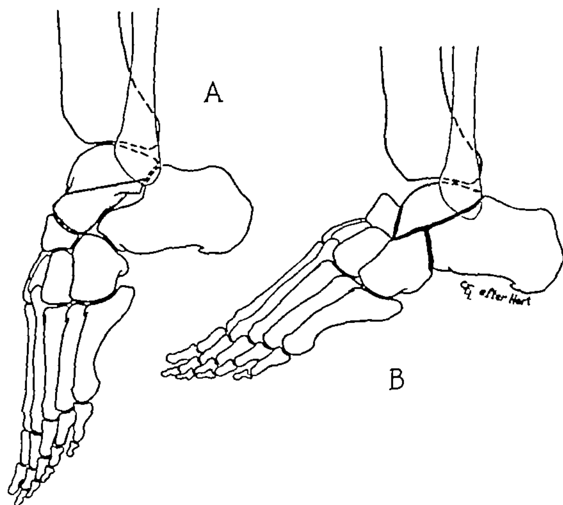


Fig. 836.—Lambrinudi operation for paralytic dropfoot. A, Stippled portion of astragalus is to be excised. B, Beak of astragalus implanted in notch in scaphoid. Calcaneocuboid joint is arthrodesed. (From Hart, V. L.: J. Bone & Joint Surg. 22: 937, 1940.)

The foot is now held in the desired position in relation to the axis of the leg and cannot be further plantarflexed because of locking of the astragalus in the ankle joint in complete equinus. The peroneal tendons are sutured and the wound closed in a routine manner.

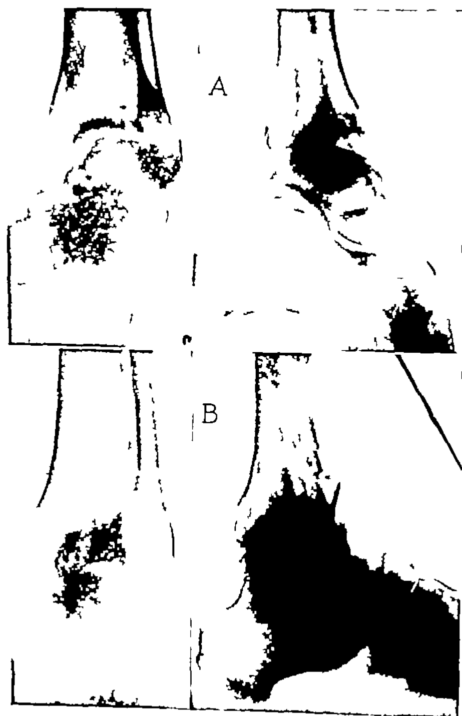
After Treatment.—See above.

Both the posterior bone block and Lambrinudi procedures have a place in the armamentarium of the orthopedist. The Lambrinudi technic must be meticulously planned before operation, with tracings and cut-outs, and at operation this plan must be implicitly followed. Unless these precautions are taken the result will often be unsatisfactory. On the other hand, a care-

lly executed bone block procedure will be followed by a larger number of od results in the hands of the operator who only occasionally performs foot abilizations and blocking procedures.

Arthrodesis of the Ankle for Equinovarus Deformity

Barr and Record have suggested arthrodesis of the ankle joint in lieu of iple arthrodesis and bone block, or panastragalar arthrodesis for severe ralytic equinovarus deformities of the feet. It is presumed that the patient past the growth period and that active muscles, suitable for transplantation



ig. 937.—*A*, Paralytic equinovarus deformity. Notice supination of body of astragalus in ankle joint. *B*, After anterior fusion of ankle. (Courtesy of Dr. J. A. Orris, Windber, Pa.)

are not available. Convinced that the major deforming factor is in the ankle joint (supination of the body of the astragalus) they do not disturb the tarsal joints (Fig 937) This procedure may also be utilized for calcaneovalgus deformities.

Technic (Barr and Record)—In cases with a severe equinovarus and cavus deformity, subcutaneous plantar fasciotomy (p 1297) and lengthening of the tendo achillis (p 1018) is performed as the first step in the procedure.

Subsequently the ankle joint is exposed by an anteromedial skin incision that follows the anterior tibial tendon. The sheath is incised and the tendon retracted By subperiosteal dissection, the internal malleolus is stripped subperiosteally to release all ligamentous attachments. The posterior tibial tendon is divided. The astragalus and distal end of the tibia on the medial and anterior aspects are freed of all soft tissue attachments. Through a second incision over the distal end of the fibula the ligaments are removed from the external malleolus and the lateral aspect of the astragalus. The articular cartilage is removed from the ankle joint sacrificing as little bone as possible. Following this procedure the foot is brought up into a neutral position, and placed in the normal amount of external torsion in relation to the leg Subsequently an arthrodesis is performed by driving an intraosseous graft into the metaphyseal region of the lower end of the tibia thence into a slot cut in the talus, preserving an anterior bridge of the metaphysis to hold the graft in place. This is carried out after the manner of Brittain. Finally additional chips are packed about the lateral recesses of the joint In a few instances, the external malleolus has been osteotomized and displaced medially in order to secure accurate apposition

After Treatment.—A plaster cast is applied from the groin to the toes with the knee at 160 degrees. The sutures are removed on the tenth day through a window A short leg cast with a walking arm is applied six weeks postoperatively and partial weight bearing permitted Two weeks later full *weight bearing is allowed all plaster immobilization* being removed ten weeks postoperatively

TENODESIS

Tenodesis, whether employed merely to maintain joint position, or to correct *a deformity has fallen into general disuse In the experience* of the majority of the orthopedic surgeons who have employed this procedure the anchored tendon sooner or later either pulls loose from its point of fixation or becomes attenuated and elongated from the effect of gravity or overpull by active antagonists.

Whitman Loop Operation for Paralytic Equinovalgus

The use of this operation is limited to cases wherein the tibialis anticus muscle alone or both the tibialis anticus and posticus muscles are paralyzed. *Armitage Whitman has modified the original loop* operation of his father Royal Whitman and combined the procedure with arthrodesis of the subastragalar and astragaloscaphoid joints.

Technic.—The subastragalar joint is exposed through an incision along the medial border of the foot, and the apposing articular surfaces of the astragalus and os calcis are excised. The astragaloscaphoid joint is similarly resected. Sufficient bone is taken from both joints to correct any osseous deformity

An anterior incision is then made from two inches above the annular ligament to the insertion of the tibialis anticus tendon, the ligament is divided the sheath of the tibialis anticus tendon is incised, and the tendon divided at its juncture with the muscle The extensor hallucis longus and extensor digitorum communis tendons are freed from one inch proximal to the bases of the toes to above the annular ligament. The peroneus tertius tendon is divided and sutured to the adjacent extensor tendon to the fifth toe. The tibialis anticus is next passed beneath the extensor tendons of the toes to the lateral side of the foot, thence brought across the top of the tendons toward the medial side of the foot, holding the extensor tendons in the midline. The tibia is exposed just above the internal malleolus, the periosteum stripped, and a shallow bed prepared for the tendon with a gouge The tibialis anticus tendon is scarified and sutured to this tibial bed under sufficient tension to hold the common extensor tendons slightly to the inner side of the midline of the foot and ankle, and at the same time allow at least 10 degrees of plantar flexion.

After Treatment.—See Triple Arthrodesis (p 1321)

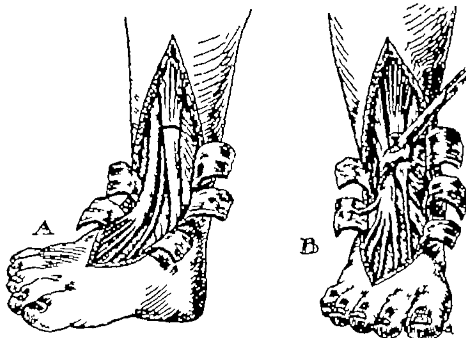


Fig. 938 —Whitman loop operation for paralytic equinovalgus. The tendon of the paralyzed tibialis anticus muscle is passed beneath the extensor tendons and reattached to the medial side of the tibia. (Redrawn from J Bone & Joint Surg. 13 121, 1931)

Tenodesis for Paralytic Calcaneus Deformity

Gallie has devised a procedure for correction of calcaneus deformity wherein a check ligament is created by inserting the tendo achillis into the shaft of the tibia, preventing dorsiflexion to an undesirable degree. The operation is less desirable than operations upon the osseous structures as the check ligament stretches after a few years of use and is no longer efficient. Transplantation of the active peroneal muscles into the os calcis has been combined with this operation.

Technic (Gallie).—An incision four inches in length is made over the tendo achillis down to the os calcis. The tendon is removed from the sheath and split in several strands or its surface is scarified. By means of retractors, the intermuscular septum covering the deep muscles of the legs is

exposed and incised in a longitudinal direction, bringing into view the bellies of the flexor hallucis longus and the tibialis posticus muscles. These structures are retracted inward, exposing the posterior surface of the shaft and lower extremity of the tibia to permit full retraction, detachment of some of the lower fibers of the flexor hallucis longus tendon from the bone may be necessary The periosteum is then incised longitudinally and reflected to the medial and lateral sides of the tibia. A section of the posterior cortex of the tibia is removed with an osteotome down to the medullary cavity the trough thus created must be *sufficiently large to allow complete burial of the tendo* achillis. The tendon is then placed in the trough and anchored under proper tension by kangaroo sutures through the tendon and adjacent portion of the tibia. The cortex is replaced and the periosteum closed.

Instead of fixing the entire tendo achillis by means of a trap door if desired, the tendon may be split in half longitudinally and the medial half severed proximally forming a tonguelike flap After exposure of the posterior surface of the tibia, a hole is drilled through the tibia in the anterior posterior plane two inches above the ankle joint A small incision is made anteriorly *over the protruding point of the drill. After removal of the drill, the* tonguelike flap of the tendo achillis is drawn through the tunnel to emerge anteriorly With the check ligament under proper tension to limit dorsiflexion to the proper degree the distal end of the flap is sutured to the soft structures on the anterior surface of the leg or fixed by sutures passed through holes drilled in the tibia

After Treatment.—With the foot in slight equinus, a boot cast is applied and retained for three weeks. At that time, the cast is changed and weight bearing is allowed for a period of four weeks. An ankle brace with a joint which limits the range of dorsiflexion is then fitted, to be worn for at least one year Weight-bearing without the brace should not be allowed for a minimum period of one year

In our experience the results from this operation are satisfactory for *only about one year after weight bearing is* begun without the brace, as the check ligament stretches and ceases to perform its intended function.

DORSAL BUNION

This *deformity usually the result of muscular* imbalance of the foot, consists of a dorsiflexed position of the shaft of the first metatarsal bone with a plantar flexion deformity of the great toe. In its early stages, the deformity is not fixed being present only on weight bearing especially in walking If the imbalance is uncorrected, however the deformity becomes fixed, though it is always more pronounced on weight bearing

Usually the entire great toe is in a position of flexion at the metatarsophalangeal joint, and in the weight bearing position the head of the first metatarsal is displaced upward thus the longitudinal axis of the metatarsal shaft may be horizontal or even directed slightly upward. The first cuneiform bone may also be tilted upward and a small exostosis and callus may form on the dorsal surface of the head of the metatarsal If the flexion at the great toe is sufficiently severe there may even be a subluxation of the metatarsophalangeal joint and, in the course of time the dorsal portion of the cartilage of the head of the metatarsal will undergo secondary *degeneration* The plantar portion of the capsule of this joint may eventually contract and not infrequently a true shortening of the flexor hallucis brevis muscle develops.

In the main there are two mechanisms of formation of this deformity The most common is a muscle imbalance acting upon the first metatarsal, causing dorsiflexion of this bone the plantar flexion of the hallux developing secondarily

Normally, the anterior tibial muscle raises the first cuneiform and the base of the first metatarsal, while the peroneus longus opposes this action In the presence of a weak or absent peroneus longus muscle however upward displacement of the first metatarsal can be produced by a strong anterior tibial muscle or its substitute With the first metatarsal displaced upward the great toe is actively flexed to establish a point of weight bearing for the medial border of the forefoot and to assist the pushoff in walking Weakness of the dorsi flexor muscles of the great toe may favor the development of this toe position

The second mechanism is a muscle imbalance which causes plantar flexion of the great toe with secondary upward displacement of the first metatarsal An example of this is found in the foot which is paralyzed except for a triceps surae group of variable strength and strong flexors of the toes. The patient utilizes the flexor muscles of the toes as an aid in steadying the foot on the leg in weight bearing and to sustain the pushoff in walking The great toe of course assumes a large share of this added function and with active use of the foot may be more or less constantly in the plantar flexed position The head of the metatarsal then displaces upward to accommodate for this weight bearing position of the great toe A strong flexor hallucis brevis muscle may obviously be a factor in the production of the deformity

Lapidus and Hammond observed that a large number of these deformities followed tendon transference in residual anterior poliomyelitis This was also found to be true at the Campbell Clinic In such cases the balanced and opposing actions of the peroneus longus and anterior tibial muscles upon the first metatarsal had not been taken into consideration in the preceding operation. Before transference of the peroneus longus tendon the effect of the loss of its normal action upon the first metatarsal should be carefully weighed

If tendon transference is feasible and the anterior tibialis is paralyzed the peroneus longus tendon or both peroneal tendons should be transferred to the region of the third cuneiform bone rather than to the region of insertion of the anterior tibial tendon. As an alternative Hammond suggests the transference of the peroneus brevis tendon to the anterior tibial insertion the peroneus longus being undisturbed.

If the triceps surae group is weak or paralyzed and the tibialis anterior and peroneus longus muscles are strong the latter muscle should not be transferred to the os calcis unless the anterior tibial tendon is transferred to the midline of the foot.

A dorsal bunion does not always follow such tendon transferences since the muscle imbalance may not be sufficiently severe to cause the deformity In progressive deformity of the great toe and metatarsal operation may simply consist of transference of either the anterior tibial or transferred peroneus longus to the third cuneiform and correction of the deformity itself may be unnecessary If the deformity is fixed however surgery must also be directed to the deformity itself as well as toward correction of the muscle imbalance

There are other less common causes for this deformity It may develop in conjunction with hallux rigidus apparently as a result of the painful dorsi flexion which is usually present in the first metatarsophalangeal joint. In

congruity of the articular surfaces and a contracture of the plantar portion of the capsule develop gradually Often bony proliferation on the dorsum of the head of the first metatarsal is pronounced resulting in a bone block. In walking the patient may then unconsciously supinate the foot and plantar flex the great toe to protect the ball of the great toe The deformity is also occasionally seen in severe congenital flat foot with associated rocker bottom deformity

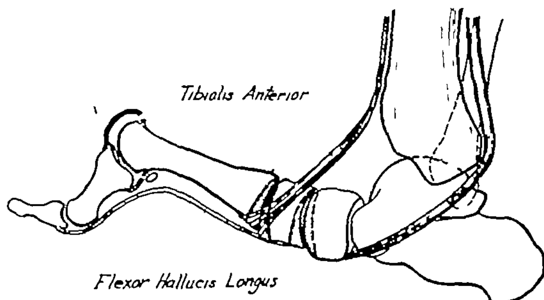


Fig. 939—Lapidus operation for elevation of first metatarsal bone with hallux equinus (dorsal bunion) Diagram shows joints to be arthrodesed. (From Lapidus, P W: J Bone & Joint Surg 22 627 1940.)

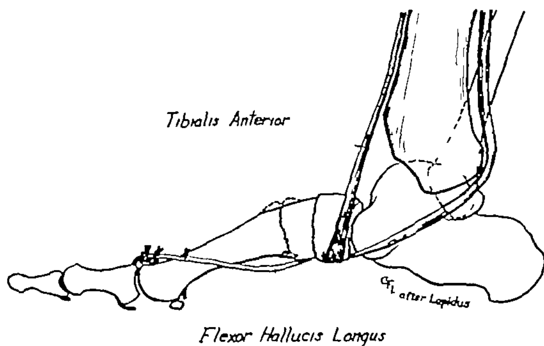


Fig. 940—Same as Fig 939 Arthrodesis completed. Flexor hallucis longus converted into a depression of first metatarsal bone Insertion of tibialis anticus transplanted posteriorly eliminating its dorsiflexion action upon first metatarsal shaft. (From Lapidus, P W J Bone & Joint Surg 22 627 1940)

Both Lapidus and Hammond have offered operative procedures to correct the deformity To eliminate the deforming force these procedures may be varied to meet the requirements of the individual case

Technic (Lapidus) —A longitudinal incision is made over the dorsomedial aspect of the metatarsophalangeal joint of the great toe exposing the dorsal capsule A dorsal tongue-shaped flap with its base attached to the phalanx is outlined and the joint opened by reflection of this flap distally Any bony proliferation of the dorsal portion of the head of the first metatarsal is removed with an osteotome A second incision is made along the dorsomedial border of the forefoot and the first metatarsocuneiform and if necessary the

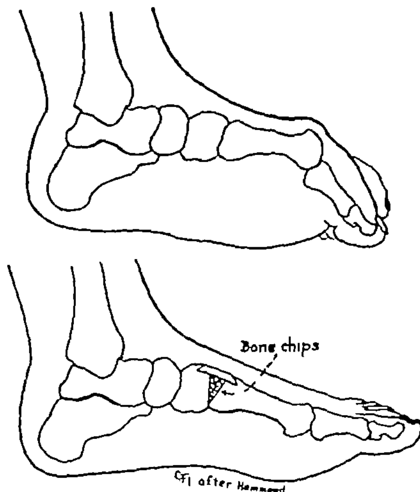


Fig. 941.—Hammond operation for hallux equinus with elevation of first metatarsal bone After osteotomy through tarsometatarsal joint, bone 1 manipulated into normal position. Residual cuneiform defect at joint filled in with bone grafts to produce arthrodesis in corrected position. (From Hammond, G *Surgery* 13 240 1943)

first scaphocuneiform joint are exposed If overactive the tibialis anticus is detached and transferred posteriorly into the tendon of the tibialis posterior thus eliminating its dorsiflexion action upon the first metatarsal shaft and reducing its leverage by shifting it backward nearer the axis of the ankle joint (Fig 939) A wedge shaped section of bone its size depending upon the type of the deformity is removed at the first cuneiform metatarsal joint and if necessary at the first scaphocuneiform joint. The base of the wedge should be inferior Lapidus points out that a metatarsus primus varus deformity if present, may be corrected at the same time by following the principles employed in his bunion operation

The flexor hallucis longus tendon is then detached from its insertion, and is pulled proximally into the incision over the forefoot. An oblique channel is drilled in the shaft of the first metatarsal from the proximal plantar aspect to the distal dorsal aspect. The end of the flexor hallucis longus tendon is brought dorsally through this channel into the wound over the toe, converting the flexor hallucis longus into a plantar flexor of the first metatarsal and eliminating its plantar flexion action upon the great toe. The flexion contracture of the great toe is completely corrected by subcutaneous plantar tenotomy and capsulotomy of the metatarsophalangeal joint just promixal to the sesamoids.

The dorsal tongue-shaped flap is plicated to place the great toe in a few degrees of dorsiflexion If hallux valgus is present, the flap is sutured with more tension on its medial side The distal end of the transplanted flexor hallucis longus tendon is then anchored into the capsular flap thus serving as a passive reinforcement of the dorsal capsule. The tendon is also sutured to the periosteum at its point of emergence from the metatarsal shaft.

After Treatment.—A plaster is applied from toes to knee with the foot in the corrected position At the end of two weeks, this is replaced by an unpadded walking cast which permits flexion of the great toe The patient is then allowed gradually to begin weight bearing Eight to ten weeks after operation the cast is removed an arch support is fitted and physical therapy instituted.

Technic (Hammond).—Through appropriate incisions, the deforming tendon is transferred to the midline of the dorsum of the foot. An arthrodesis of the joint or joints at which dorsiflexion occurs is performed to correct the metatarsal displacement (Fig 941) Through a dorsal longitudinal incision of an adequate length the dorsal aspect of the joint is exposed the capsule reflected and the cartilage excised A rectangular section of bone, one fourth to three-eighths inch deep is removed from the dorsal aspects of the contiguous bones and these two sections of bone are cut into small pieces. The first metatarsal bone is manipulated into normal position as the dorsal aspects of the contiguous bones separate dorsally, a wedge-shaped defect is produced in the joint. A bone graft of sufficient size to fill the rectangular defect and to bridge the dorsal gap in the joint is removed from the tibia and placed in the prepared bed maintaining the metatarsal in correct position. Any space remaining in the joint is filled with small bone grafts. If arthrodesis of both the first metatarsocuneiform and first scaphocuneiform joints seems advisable the same technic is followed the tibial bone graft extending from the scaphoid across the first cuneiform into the base of the first metatarsal. If manipulation does not correct the flexion deformity of the great toe, a capsulotomy of the plantar portion of this joint may be performed.

After Treatment.—See above

KNEE

The common deformities associated with paralysis of the muscles which act across the knee joint are (1) flexion contracture, with or without some degree of subluxation and external rotation of the tibia, and (2) genu recurvatum

The triad of deformities about the knee, consisting of flexion, valgus, and external rotation of the tibia on the femur may follow an uncorrected contracture of the iliotibial band (p 1372) Yount, Forbes, and Irwin advise

division of the band and the lateral intermuscular septum above the knee. If the deformity is of long standing more extensive procedures are indicated

Flexion contracture arises also from paralysis of the quadriceps muscle when the hamstring muscles are unaffected or only partially paralyzed When the biceps is stronger than the internal hamstring muscles the leg is not only forced into external rotation but there is a genu valgum deformity as well and often posterior subluxation The valgus, however differs from that incident to rickets, being induced entirely by external rotation of the tibia and stretching of the internal lateral ligament of the knee as described above rather than by bony irregularity During the process of growth, the bony structures may become altered in contour to conform to the flexion and rotation

In mild contractures, correction may be secured by conservative means. In severe fixed contractures posterior capsulotomy (p 1030) and lengthening of the hamstring tendons may also be necessary If genu valgum is present after correction of the flexion, normal alignment may be restored later by subcutaneous supracondylar osteotomy of the femur Osteotomy is seldom required, however when the articular surfaces are apposed in complete extension, the alignment of the extremity usually is satisfactory Occasionally torsion deformities of the femur or tibia from continued pull of unopposed muscles and from growth in the line of stress must be corrected by rotation osteotomy

Genu recurvatum deformity is the opposite of flexion contracture of the knee and is in reality hyperextension, being produced by the action of the normal quadriceps muscle in the presence of weak or paralyzed hamstring muscles. Genu recurvatum of slight degree may cause disability but is nevertheless desirable since the knee is thus stabilized in walking when genu recurvatum is exaggerated, however there is material deformity and disability

Surgical procedures devised for correction of genu recurvatum consist of bone block operations subcondylar tibial osteotomies, tenodeses ligament fixation, and arthrodeses These are described subsequently in the section on stabilization of the knee (p 1359)

TENDON TRANSFERENCE

Tendon transference at the knee joint is employed almost exclusively to compensate for paralysis of the quadriceps muscle. The disability from paralysis of this muscle is severe, as the knee is exceedingly unstable particularly if the slightest fixed flexion deformity is present. Tendon transference is unnecessary for paralysis of the hamstring muscles, since flexion is accomplished by gravity as the hip is flexed in walking In the presence of slight recurvatum deformity of the knee the patient often walks well if the flexors of the hip and gastrocnemius muscle are active as the step is completed, the knee is locked by hyperextension.

Several muscles are available for transference to the quadriceps tendon the biceps femoris, semitendinosus, semimembranosus, sartorius and tensor fasciae femoris. In our experience the biceps femoris muscle has proved to be the most suitable. Transference of the hamstring tendons is contraindicated unless one other flexor in the thigh, as well as the gastrocnemius muscle, which also acts as a knee flexor is functioning Transference of the tensor fasciae femoris and sartorius muscles, although more satis-

factory from an anatomic and physiologic point of view usually is inadequate since these muscles do not have sufficient power to fulfill the function of the quadriceps Further in our opinion transference of the tensor fasciae femoris muscle should be avoided as far as possible as this structure aids in maintaining the lateral stability of the knee

Prior to tendon transference about the knee, any slight flexion deformity must be corrected, in fact, slight hyperextension is desirable. (See Ankylosis and Deformity) If the contracture is of only 10 to 15 degrees, supracondylar osteotomy may be carried out at the time of the tendon transference or if the quadriceps muscle possesses considerable power and there is a slight recurvatum supracondylar osteotomy is sufficient to produce a relatively stable knee.

Flexion deformity of the hip genu valgum and excessive contracture of the tendo achillis are other deformities frequently found in conjunction with paralysis of the quadriceps. These also should be corrected before tendon transference.

Arrangements for regular active physical therapy should be made as this is essential after operation

Transference of Hamstring Muscles for Paralysis of Quadriceps Muscle

The hamstring muscles most often utilized for tendon transference in *paralysis of the quadriceps muscle are the biceps femoris or semitendinosus.* If the power of the biceps is not adequate these may be transferred together as a rule, however transference of the biceps femoris muscle is sufficient.

O'Donoghue advises routine transference of both the biceps and semitendinosus tendons in order to obtain a more uniform upward pull on the patella, and more adequate and complete extension of the knee In some cases he has observed lateral patellar subluxation following biceps transfer alone

Before removal of the biceps femoris from the posterior aspect of the knee joint, not only must the hip muscles be adequate but the other muscle groups as well must have supporting power This is particularly true of the triceps surae group which furnishes a powerful support to the back of the knee If this group is paralyzed or materially weakened removal of the biceps tendon will be followed by genu recurvatum Thus, according to Crego and Fischer the ideal cases for biceps femoris transplant are those wherein the hip and calf muscles are fairly strong and because of extensor paralysis, walking without supporting apparatus is not practicable.

Technic.—*An incision is made along* the anteromedial aspect of the knee joint to conform to the medial border of the quadriceps tendon, the patella, and patellar tendon. The lateral border of the incision is retracted bringing into view the patella and quadriceps tendon. The lateral aspect of the thigh and leg are then incised longitudinally from a point three inches below the head of the fibula to the juncture of upper and middle thirds of the thigh. The common peroneal nerve is in close proximity to the *medial border of the* biceps tendon and should be isolated and retracted.

The biceps tendon together with a thin portion of the head of the fibula, is freed with an osteotome. Precautions are taken to avoid severance of the fibular collateral ligament which lies firmly adherent to the biceps tendon at its point of insertion. The biceps tendon is dissected upward with its mus

cle belly as far as the limit of the incision will permit. In order that the line *of pull of the transferred tendon and muscle may be as oblique as possible*, the origin of the short head of the biceps femoris must be freed upward to the point of entrance of its nerve and blood supply. A subcutaneous tunnel is formed from the first incision to the internal thigh incision, the tunnel being sufficiently wide to permit the transferred muscle belly to glide freely. To further increase the obliquity of pull of the transferred muscle, the iliotibial band, the fascia of the vastus internalis and the external intermuscular septum are divided at a point below the level of the passage of the transferred muscle.

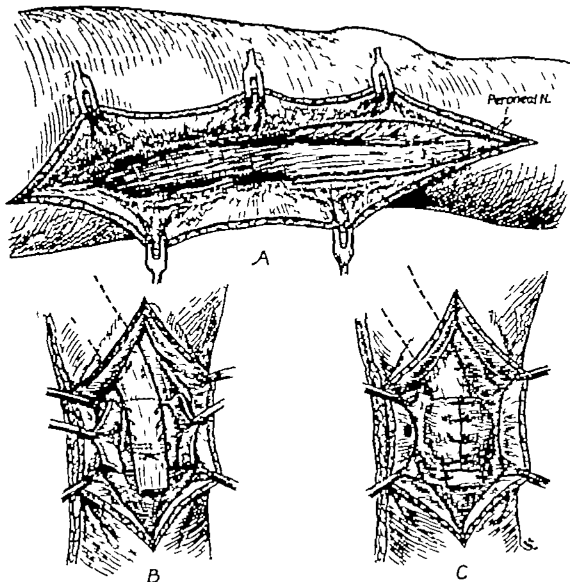


Fig. 842.—Transference of biceps femoris muscle for paralysis of quadriceps muscle. *A* Biceps tendon detached, together with a fascial prolongation, rerouted through subcutaneous structures to patella, and reattached as illustrated in *B* and *C*

Beginning distally over the insertion of the medial hamstring tendons into the tibia, a third incision is extended proximally along the posteromedial aspect of the knee to the middle third of the thigh. The semitendinosus tendon is a small round tendon, which is inserted on the inner side of the tibia as far forward as the crest and lies behind the tendon of the sartorius muscle and below that of the gracilis. The tibial insertion of the semitendinosus tendon is severed and the muscle is freed to the middle third of the

thigh. By means of a suture placed through this end, as described previously the tendon is passed subcutaneously to emerge in the wound over the knee joint.

The fascia quadriceps tendon, and periosteum are incised over the patella by an I-shaped incision, and the soft tissues are stripped from the front of the patella. A tunnel is next drilled transversely through the patella at the junction of the middle and upper thirds, a No 19 drill being used for the purpose. If necessary, the tunnel may be enlarged with a small curette. The biceps tendon is then placed in line with and over the quadriceps tendon, the patella and patellar tendon. By means of a wire loop inserted through the tunnel from the inner aspect the outer suture is passed through the tunnel from without inward similarly, the inner suture is drawn through the tunnel from within outward. The knee is placed in extension or hyperextension and the suture is drawn taut, approximating the end of the biceps tendon to the denuded upper border of the patella. The sutures are tied across the front of the tendon. If only the biceps tendon is transferred the I-shaped flaps of periosteum quadriceps tendon, and capsule are closed With interrupted sutures the biceps tendon is fixed to the medial side of the quadriceps tendon. The semitendinosus, if also transferred is placed over the biceps tendon and the two are sutured together with interrupted stitches, with additional sutures above and below through the quadriceps and patellar tendons.

After Treatment.—With the knee in full extension, a long plaster cast is applied from the groin to the toes. To prevent swelling the extremity is elevated by raising the foot of the bed rather than by pillows otherwise flexion of the hip may place too much strain upon the transferred tendon.

At the end of three weeks physical therapy and active and passive exercises are begun. At eight weeks weight bearing is permitted, the extremity being supported by a control dial knee brace with the joint locked in extension. Motion is not allowed in the brace until the transferred tendon acquires sufficient power to extend the knee against considerable force To prevent overstretching or strain of the tendon a night splint is worn for a period of at least six weeks and a day brace for at least twelve weeks.

Transference of Sartorius Muscle for Paralysis of Quadriceps Muscle

Technic.—An incision is begun at the tibial tubercle, curved across the insertion of the sartorius muscle, thence proximally along the medial aspect of the thigh, and ended on the anterior surface of the thigh at the juncture of the middle and upper thirds. *After subcutaneous dissection, the lower* portion of the skin incision is retracted laterally, bringing into view the patella and patellar tendon the inner border is retracted medially to expose the sartorius muscle. The insertion of the sartorius tendon, which is *just anterior to the insertions of the semitendinosus and gracilis* tendons, is severed and the tendon and muscle are dissected free to the middle of the thigh, leaving the sheath as intact as possible. Several small vessels are necessarily divided during this procedure. The saphenous nerve lies near the *posterior border of the sartorius muscle* and should be elevated and retracted otherwise, the nerve supply is not endangered. A suture of No. 2 chromic catgut braided silk or linen is now placed in the distal end of the tendon, continued along its inner border for two inches, thence across and *down* the outer border to the end again. The two strands of the suture should remain free. The tendon is then passed subcutaneously from the middle of

the thigh to the patella. The sartorius tendon is fixed to the quadriceps tendon, patella and patellar tendon as described for transference of the biceps femoris tendon (p 1354)

After Treatment.—See above

Transference of Tensor Fasciae Femoris and Sartorius Muscles for Paralysis of Quadriceps Muscle

Technic (Ober) —The sartorius muscle and tendon are freed by a technic similar to that just described A second incision eight inches long is made over the ligamentum patellae curving outward and proximally along the iliotibial band The latter is dissected free from the fibula and surrounding

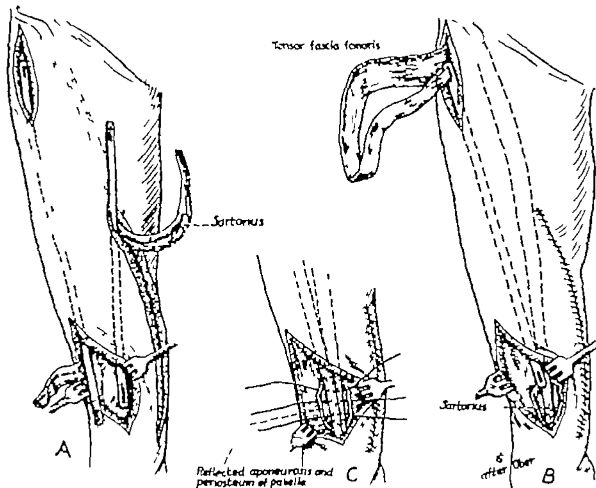


Fig. 943.—Transference of tensor fasciae femoris and sartorius muscles for paralysis of the quadriceps muscle (Ober) *A* Iliotibial band freed from fibula, to be withdrawn from proximal wound. Sartorius dissected free, to be withdrawn into wound over patella. *B*, Tensor fasciae femoris rerouted subcutaneously to patella. *C* Sartorius and iliotibial band sutured to ligamentum patellae and covered with reflected aponeurosis and periosteal flaps of patella. (Redrawn from Ober F R. New England J Med. 209: 52, 1933)

structures, forming a flap three-fourths inch wide A third incision is now made over the junction of the fascia with its muscle in the upper third of the thigh. The two wounds are connected by a subcutaneous tunnel, and the loose flap of fascia with the tendon attached is withdrawn from the proximal wound The belly of the tensor fasciae femoris muscle is then freed from the surrounding structures. The lower end of the second incision is dissected medially to expose the quadriceps tendon and patella and the fascia and aponeurosis of the patella are stripped longitudinally The quadriceps tendon

thigh By means of a suture placed through this end, as described previously the tendon is passed subcutaneously to emerge in the wound over the knee joint.

The fascia, quadriceps tendon, and periosteum are incised over the patella by an I-shaped incision, and the soft tissues are stripped from the front of the patella. A tunnel is next drilled transversely through the patella at the junction of the middle and upper thirds, a No 19 drill being used for the purpose If necessary the tunnel may be enlarged with a small curette. The biceps tendon is then placed in line with and over the quadriceps tendon, the patella and patellar tendon. By means of a wire loop inserted through the tunnel from the inner aspect, the outer suture is passed through the tunnel from without inward, similarly, the inner suture is drawn through the tunnel from within outward The knee is placed in extension or hyperextension and the suture is drawn taut, approximating the end of the biceps tendon to the denuded upper border of the patella The sutures are tied across the front of the tendon If only the biceps tendon is transferred, the I-shaped flaps of periosteum quadriceps tendon and capsule are closed. With interrupted sutures the biceps tendon is fixed to the medial side of the quadriceps tendon. The semitendinosus, if also transferred is placed over the biceps tendon and the two are sutured together with interrupted stitches, with additional sutures above and below through the quadriceps and patellar tendons.

After Treatment.—With the knee in full extension, a long plaster cast is applied from the groin to the toes To prevent swelling the extremity is elevated by raising the foot of the bed rather than by pillows otherwise flexion of the hip may place too much strain upon the transferred tendon.

At the end of three weeks physical therapy and active and passive exercises are begun At eight weeks weight bearing is permitted the extremity being supported by a control dial knee brace with the joint locked in extension. Motion is not allowed in the brace until the transferred tendon acquires sufficient power to extend the knee against considerable force To prevent overstretching or strain of the tendon a night splint is worn for a period of at least six weeks and a day brace for at least twelve weeks.

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After Treatment.—See above

Transference of Tensor Fasciae Femoris and Sartorius Muscles for Paralysis of Quadriceps Muscle

Technic (Ober)—The sartorius muscle and tendon are freed by a technic similar to that just described A second incision eight inches long is made over the ligamentum patellae curving outward and proximally along the iliotibial band The latter is dissected free from the fibula and surrounding

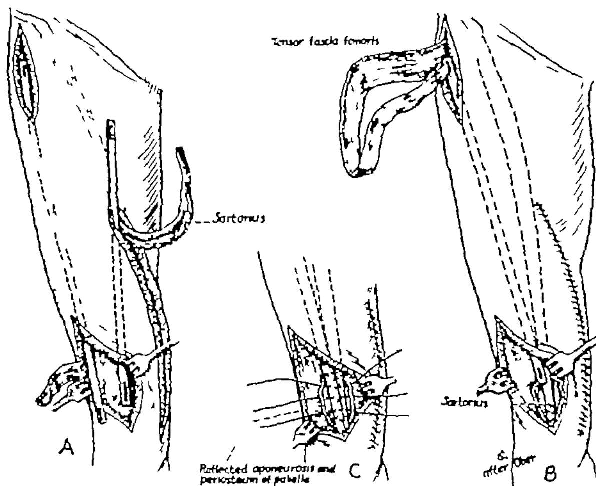


Fig. 541.—Transference of tensor fasciae femoris and sartorius muscles for paralysis of the quadriceps muscle (Ober) *A* Iliotibial band freed from fibula, to be withdrawn from proximal wound. Sartorius dissected free, to be withdrawn into wound over patella. *B*, Tensor fasciae femoris rerouted subcutaneously to patella. *C* Sartorius and iliotibial band sutured to ligamentum patellae and covered with reflected aponeurosis and periosteal flaps of patella. (Redrawn from Ober F R. New England J Med. 209: 52, 1933.)

structures, forming a flap three-fourths inch wide. A third incision is now made over the junction of the fascia with its muscle in the upper third of the thigh. The two wounds are connected by a subcutaneous tunnel and the loose flap of fascia with the tendon attached is withdrawn from the proximal wound The belly of the tensor fasciae femoris muscle is then freed from the surrounding structures. The lower end of the second incision is dissected medially to expose the quadriceps tendon and patella, and the fascia and aponeurosis of the patella are stripped longitudinally The quadriceps tendon

is next incised from a point above the patella across the bone into the patellar tendon and its edges are reflected to each side for one-half inch An X-suture of silk is placed in the free end of the sartorius tendon and another in the end of the iliotibial band By means of a fascia carrier, the free end of the iliotibial band and the end of the sartorius tendon are passed subcutaneously into the wound over the quadriceps tendon. With the knee extended and the thigh held in 135 degrees flexion the sartorius tendon is firmly sutured to the patellar tendon The iliotibial band is then placed over the sartorius tendon and likewise sutured to the patellar tendon. The medial and lateral edges of this band are sutured to the reflected edges of the aponeurosis of the patella and to the edge of the sartorius muscle which lies on the bare patella.

After Treatment.—See p 1356

Transference of Tensor Fasciae Femoris and Biceps Muscles for Paralysis of Quadriceps Muscle

Having observed that a portion of the gluteus maximus is inserted into the iliotibial band and acts conjointly with the tensor fasciae femoris muscle, Yount has devised a method of utilizing this portion of the gluteus maximus as well as the tensor fasciae femoris and the biceps muscles for paralysis of the quadriceps. The procedure is necessarily more radical than the usual measures employed in quadriceps paralysis.

Technic (Yount)—A longitudinal incision is begun at the greater trochanter carried along the lateral aspect of the thigh then curved toward the middle of the dorsal surface of the thigh to the patella and across the patella to the tibial tubercle The edges of the skin are reflected back to expose fully the fascia lata from the middle of the thigh anteriorly to the posterior edge Proximally dissection is carried down to the insertion of the gluteus maximus muscle into the fascia lata The biceps tendon is isolated at the head of the fibula, divided through two-thirds of its thickness, and dissected proximally until the muscle fibers of the short head are exposed. Since there is no advantage in utilizing the short head of the biceps, this part of the muscle is separated from the long head on the other hand by retaining the short head as a flexor of the knee, the development of genu recurvatum is prevented The insertion of the iliotibial band is freed subperiosteally from the tuberosity of the tibia and a strip of the band one-half inch wide is dissected free from the lateral aspect of the tuberosity thence across the surface of the knee joint to that part of the iliotibial band which is well defined Two inches above the knee joint, this strip is widened gradually toward the upper third of the thigh and dissected free at its proximal end, together with the insertions of the gluteus maximus and tensor fasciae femoris muscles. In order to transpose these structures to a position which approximates that of the quadriceps, the inner lip of the cut fascia lata is folded upon itself toward the medial aspect of the thigh The tube thus formed is so placed as to extend obliquely from the lateral surface of the thigh proximally to the dorsal surface distally The transplant of the tensor fasciae femoris is drawn through the tube from the top Into a separate opening two inches distal to the proximal end, the long head of the biceps is likewise inserted. After emergence from this tunnel, the biceps is stitched to the fascial transplant and both structures are sutured to the quadriceps tendon the latter having first been incised in the midline one and one-half inches above the patella.

The prolongation of the fascial transplant is divided into two sections and embedded in drill holes in the patella

The end results of tendon transference for paralysis of the quadriceps muscle are relatively satisfactory Regardless of the muscle transferred, the patient usually adjusts himself readily to the changed mechanics of muscle function The power of extension varies in some cases, active extension against considerable force is possible in others the transferred muscle is too weak to extend the knee against gravity The improvement in gait is commensurate with the re-establishment of muscle power which is practically always sufficient to permit walking without a hand-on the knee gait

STABILIZATION OF THE KNEE JOINT
GENU RECURVATUM

Genu recurvatum incident to infantile paralysis is of two types The one is characterized by the presence of structural bony changes, while the other arises from relaxation of the soft structures on the posterior aspect of the knee joint

The fundamental cause of the first type is the lack of sufficient power in the quadriceps femoris muscle group to lock the knee in extension against resistance Typically the hamstrings may be of normal power and are not stretched the calf muscles may be normal and the back of the heel may contact the floor when weight is borne on that extremity The knee is prevented from buckling' or giving way because of this compensatory mechanism in time however bony changes develop in the tibial condyles and in the upper third of the tibial shaft The condyles become elongated posteriorly and the angle of the articular surface of the tibia which is normally 90 degrees to the long axis of the shaft becomes more acute A posterior bowing is usually present in the upper third of the shaft and even partial subluxation of the tibia may gradually ensue

In the second type wherein the knee becomes hyperextended from relaxation of the soft tissues weakness of the calf and hamstring muscles is the underlying cause This type develops more rapidly than the first, and stretching of the posterior capsular ligaments follows stretching of the hamstring and gastrocnemius muscles. A calcaneus or calcaneovalgus deformity of the foot is often present on the same side The gait is characterized by a lack of spring in the step and with continued use of the extremity further stretching of the soft tissues takes place

Irwin described the above differences in type and points out that surgical procedures to correct genu recurvatum must fulfill two requirements first the mechanical alignment of the hyperextended extremity must be properly restored, and second following restoration of the mechanical alignment the underlying causative factors of the deformity must be so altered that the hyperextension will not recur The prognosis following correction of the first type is excellent. The skeletal deformity is first corrected and this is followed by transplantation of one or more of the hamstrings into the patella In the second type the underlying cause cannot be removed as there is no available musculature to transplant thus the deformity may recur even after correction of the malalignment Soft tissue shortening procedures though successful for a time may sooner or later undergo the fate of any tenodesis, that is the soft tissues may become stretched and elongated Frequently a long leg brace is eventually necessary to maintain these ex

tremities in good alignment. Arthrodesis of the knee is a satisfactory solution to this problem most patients will not accept fusion however, preferring permanent use of a brace to loss of knee motion

Irwin has described an osteotomy of the upper end of the tibia to correct hyperextension. The technic is relatively simple and has been employed in this clinic in a few cases, with uniform success It is similar to the procedures described by Brett and Campbell (p 542)

Operations on the Osseous Structures for Genu Recurvatum

Technic (Irwin) —A section of the shaft of the fibula approximately one inch in length is removed at a point just below the neck. The defect is packed with bone shavings made from the sectioned piece of bone. The periosteum

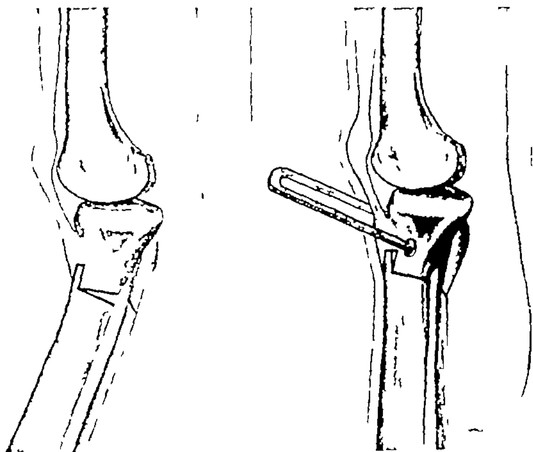


Fig 944.—Irwin osteotomy for genu recurvatum. (From Irwin, C. E. J. A. M. A. 120: 277 1942.)

and overlying tissues are closed in the routine manner Through a second incision the upper fourth of the tibia is exposed and osteotomized (see Fig 944) the joint being undisturbed. With a thin osteotome, the tongue attached *to the lower fragment is cut out of the* anterior cortex. The use of a thin osteotome to cut out the tongue prevents the loss of bone substance around the edges and the tongue fits snugly when later replaced in the recess of the upper fragment. A Kirschner wire is now passed through the distal end of the proposed upper fragment before the tibial shaft is completely divided. The wire should be inserted at a right angle to the vertical axis of the knee *joint and parallel to its lateral* plane. The osteotomy is then completed with

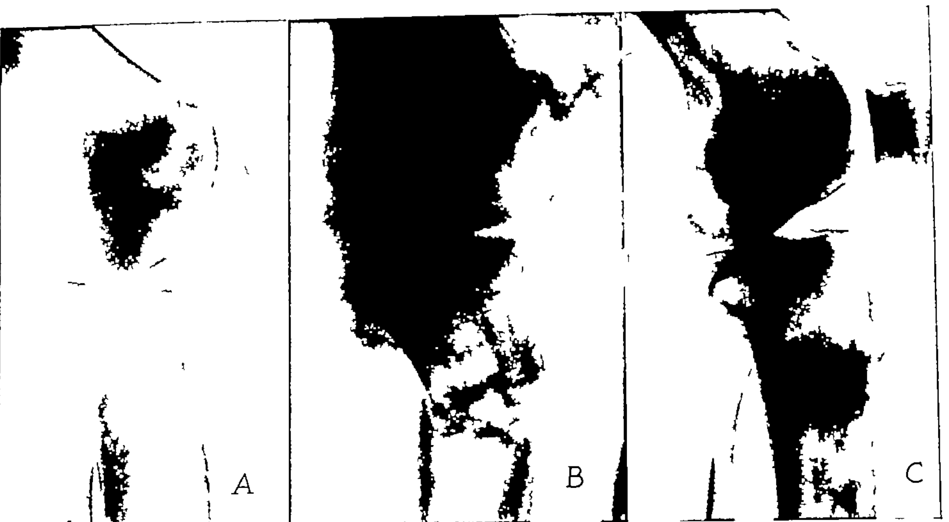


Fig. 946.—*A* Recurvatum secondary to tilting of tibial plateau. *B* After Campbell technic (p. 843) for recurvatum. *C* Five months after operation.

either a Gigli saw or an osteotome. The proximal part of the distal fragment is lifted from its periosteal bed and a wedge of bone of predetermined size is removed from the shaft, the base of the wedge corresponding to the posterior cortex. The tongue is replaced in its recess in the upper fragment and the two ends of fragments are pushed firmly together (Fig 944) The periosteum which is quite thick in this area is firmly fastened over the tongue. This is sufficient fixation to keep the fragments in position until a cast can be applied.

After Treatment.—The patient is placed on a fracture table and the extremity is suspended to an overhead arm by means of a chain fastened through the Kirschner bow The weight of the extremity in addition to pressure applied to the anterior aspect of the distal portion of the thigh hyperextends the proximal fragment to its fullest extent. With the extremity in this position a single spica extending from the iliac crest down to and including the wire in the hyperextended fragment, is applied This portion of the cast is allowed

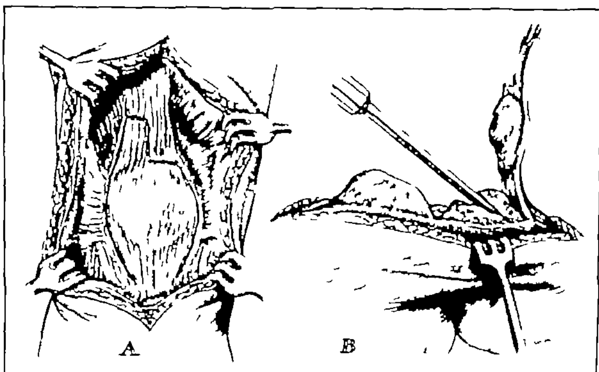


Fig. 946.—Operation for genu recurvatum (Campbell) *A* Quadriceps lengthened and patella and ligamentum patellae freed. *B* Distal end of patella freed of soft tissue attachments and denuded to spongy bone. Osseous flap pried forward from anterior aspect of tibial condyle.

to set, the pelvis femur and proximal fragment of the tibia thus being immobilized as a unit. The distal fragment remains free for manipulation in any direction desired and may be flexed to correct the hyperextension, rotated internally or externally to correct any associated torsion or moved from side to side to overcome any varus or valgus of the tibia The desired position having been obtained the cast is completed Postoperative roentgenograms are made to check the position and general alignment. If necessary further changes in position of the fragment are made by wedging the plaster distal to the wire at the end of ten to fourteen days postoperatively The Kirschner wire is removed after six weeks, and the spica is replaced by a long leg cast extending from toe to the groin. Eight weeks are usually sufficient for complete union. A full range of joint motion should be restored before any secondary procedure to alter the underlying causative factors is carried out.

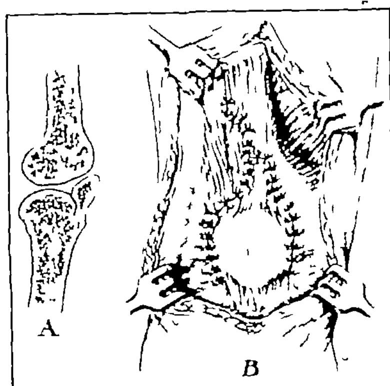


Fig. 947.—Same as Fig. 946. *A* Patella inserted into cleft in tibia. *B* Closure of wounds so as to lengthen quadriceps tendon.

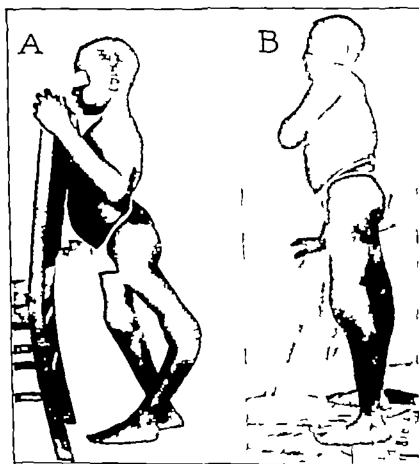


Fig. 948.—*A* Extreme genu recurvatum deformity. *B* Ten months after Campbell procedure.

In 1917 Campbell devised an operation for the correction of genu recurvatum based upon a principle which so far as could be ascertained, differed from those embodied in other surgical measures previously employed for *paralytic joints. This procedure featured the construction of an anterior* block or obstruction of bone to limit undesirable motion. The patella was fused to the tibia, reproducing in effect an "olecranon process" at the knee. In 1919 the same principle was applied to the ankle in the *posterior bone* block operation for drop foot (p 1337) and has since been used by Putti as an anterior bone block in the ankle and posterior block in the elbow and by Gill and others as a posterior bone block for the ankle. At present, this procedure is used only in exceptional cases.

Technic (Campbell).—The skin and superficial tissues are incised longitudinally over the medial aspect of the patella and patellar ligament a distance of five or six inches. The edges of the wound are retracted and the quadriceps tendon is divided above the patella by a Z-shaped incision. The capsule of the knee joint on each side of the patella is then opened and the patella is drawn downward exposing the interior of the joint. The ligamentum mucosum is divided and a portion of the infrapatellar fat pad excised. The lower one-half to three fourths inch of the patella is denuded of soft tissue attachments *and the cartilage is removed from the distal three-fourths inch of the* articular surface to spongy bone An osteotome is next driven vertically downward into the upper anterior aspect of the tibia and the anterior flap of bone is pried forward creating a greenstick fracture at its base. The patella is inserted into this cleft in the tibia, and the periosteum of the patella is sutured to the periosteum of the tibia about the margin of the cavity Finally the quadriceps tendon is reunited without tension the joint capsule sutured, and the wound closed

After Treatment.—The extremity is placed in a cast which immobilizes the knee at 160 degrees flexion After eight weeks, a brace with a stop-joint at the knee is fitted and worn until roentgenograms demonstrate complete bony fusion. The position in which the knee becomes blocked must be carefully watched and controlled throughout the period of convalescence. *Complete extension or even slight hyperextension or recurvatum is essential.* as walking with the knee in flexion produces an unnecessary limp and excessive strain upon the quadriceps muscle

Operations on the Soft Structures for Genu Recurvatum

Genu recurvatum may be corrected by surgical procedures on the tendons and ligaments as well as on the osseous structures. Heyman, in 1924 was the first to describe such an operation. In his original technic reconstruction of the lateral collateral ligaments was performed in a manner similar to that described by Edwards, though the attachments were secured on the femoral condyle *as far posteriorly as possible* At least a fair amount of strength must remain in the quadriceps muscle in order to lock the knee, and there must be sufficient strength in other muscles of the extremity and stability at the hips and foot *to enable the patient to walk without a brace.* Of seven operations of the original type which he has performed good stability has been maintained in five at most, recurrent deformity was of a mild degree and did not necessitate the use of a brace. In his two failures, osteoporosis of the femoral condyles was present in sufficient degree to prevent secure anchorage of the reconstructed ligaments.

Technic (Heyman)—Through a longitudinal incision over the lateral aspect of the knee, the biceps tendon is exposed and divided just above the level of the joint If the biceps muscle is not paralyzed the tendon is not wholly severed instead, a longitudinal flap is raised (Fig 949) A rectangular flap of fascia lata approximately three inches long is dissected free with its base at the femoral condyle as far posteriorly as possible and the flap is folded to make a strong narrow band The knee is then flexed to an angle of about 110 degrees, and by means of a small staple, the proximal end of the distal segment of the biceps tendon is attached in a groove prepared on the femoral condyle as far posterior as possible The band of fascia lata is similarly secured into the head of the fibula, strong tension being meanwhile exerted on the band (Fig 950)

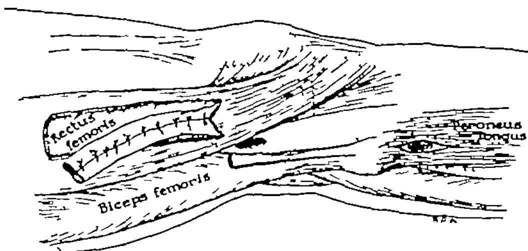


Fig. 949—Heyman procedure for genu recurvatum. If biceps is not paralyzed, one-half of biceps tendon is anchored to femoral condyle otherwise, entire tendon is utilized. (From Heyman, C. H. J Bone & Joint Surg 29 644, 1947)

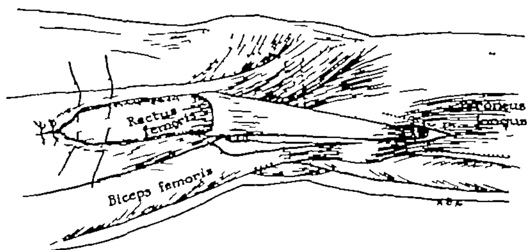


Fig. 950—Same as Fig. 949 Flap of fascia lata turned distally End anchored into head of fibula by staples. (From Heyman, C. H. J Bone & Joint Surg. 29 644 1947)

A longitudinal incision is then made over the medial aspect of the joint, exposing the gracilis and semitendinosus tendons. These tendons are divided just above the level of the joint, and are freed by blunt dissection to their insertion on the anteromedial surface of the tibia. A groove is prepared on the medial condyle as far posterior as possible and under strong tension the proximal ends of the distal segments of the tendons are secured in the prepared

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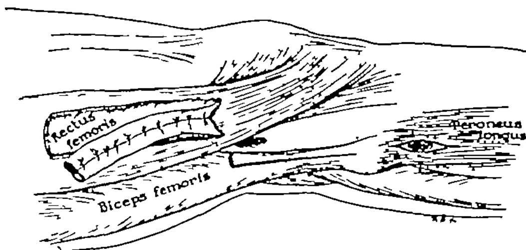


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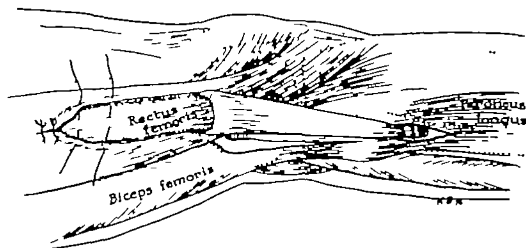


Fig. 950.—Same as Fig. 949. Flap of fascia lata turned distally. End anchored into head of fibula by staples. (From Heyman, C. H. J Bone & Joint Surg. 29: 644, 1947.)

A longitudinal incision is then made over the medial aspect of the joint exposing the gracilis and semitendinosus tendons. These tendons are divided just above the level of the joint, and are freed by blunt dissection to their insertion on the anteromedial surface of the tibia. A groove is prepared on the medial condyle as far posterior as possible and under strong tension, the proximal ends of the distal segments of the tendons are secured in the prepared

In 1917 Campbell devised an operation for the correction of genu recurvatum based upon a principle which, so far as could be ascertained differed from those embodied in other surgical measures previously employed for paralytic joints. This procedure featured the construction of an anterior block or obstruction of bone to limit undesirable motion. The patella was fused to the tibia, reproducing in effect an "olecranon process" at the knee. In 1919 the same principle was applied to the ankle in the posterior bone block operation for drop foot (p 1337) and has since been used by Putti as an anterior bone block in the ankle and posterior block in the elbow, and by Gill and others as a posterior bone block for the ankle. At present, this procedure is used only in exceptional cases.

Technic (Campbell).—The skin and superficial tissues are incised longitudinally over the medial aspect of the patella and patellar ligament a distance of five or six inches. The edges of the wound are retracted and the quadriceps tendon is divided above the patella by a Z-shaped incision. The capsule of the knee joint on each side of the patella is then opened and the patella is drawn downward exposing the interior of the joint. The ligamentum mucosum is divided and a portion of the infrapatellar fat pad excised. The lower one half to three-fourths inch of the patella is denuded of soft tissue attachments and the cartilage is removed from the distal three fourths inch of the articular surface to spongy bone. An osteotome is next driven vertically downward into the upper anterior aspect of the tibia, and the anterior flap of bone is pried forward creating a greenstick fracture at its base. The patella is inserted into this cleft in the tibia, and the periosteum of the patella is sutured to the periosteum of the tibia about the margin of the cavity. Finally the quadriceps tendon is reunited without tension the joint capsule sutured and the wound closed

After Treatment.—The extremity is placed in a cast which immobilizes the knee at 160 degrees flexion. After eight weeks, a brace with a stop-joint at the knee is fitted and worn until roentgenograms demonstrate complete bony fusion. *The position in which the knee becomes blocked must be carefully watched and controlled throughout the period of convalescence.* Complete extension or even slight hyperextension or recurvatum is essential, as walking with the knee in flexion produces an unnecessary limp and excessive strain upon the quadriceps muscle

Operations on the Soft Structures for Genu Recurvatum

Genu recurvatum may be corrected by surgical procedures on the tendons and ligaments as well as on the osseous structures. Heyman in 1924, was the first to describe such an operation. In his original technic reconstruction of the lateral collateral ligaments was performed in a manner similar to that described by Edwards, though the attachments were secured on the femoral condyle *as far posteriorly as possible*. At least a fair amount of strength must remain in the quadriceps muscle in order to lock the knee and there must be sufficient strength in other muscles of the extremity and stability at the hips and foot to enable the patient to walk without a brace. Of seven operations of the original type which he has performed good stability has been maintained in five at most recurrent deformity was of a mild degree and did not necessitate the use of a brace. In his two failures, osteoporosis of the femoral condyles was present in sufficient degree to prevent secure anchorage of the reconstructed ligaments.

Technic (Heyman)—Through a longitudinal incision over the lateral aspect of the knee the biceps tendon is exposed and divided just above the level of the joint If the biceps muscle is not paralyzed the tendon is not wholly severed instead, a longitudinal flap is raised (Fig 949) A rectangular flap of fascia lata approximately three inches long is dissected free with its base at the femoral condyle as far posteriorly as possible and the flap is folded to make a strong narrow band The knee is then flexed to an angle of about 110 degrees and by means of a small staple the proximal end of the distal segment of the biceps tendon is attached in a groove prepared on the femoral condyle as far posterior as possible The band of fascia lata is similarly secured into the head of the fibula, strong tension being meanwhile exerted on the band (Fig 950)

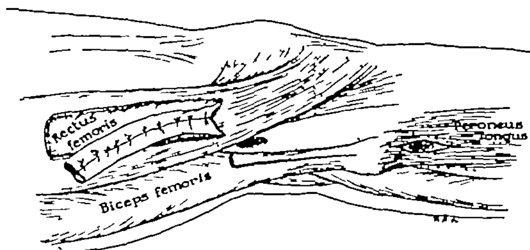


Fig. 949—Heyman procedure for genu recurvatum. If biceps is not paralyzed, one-half of biceps tendon is anchored to femoral condyle otherwise, entire tendon is utilized. (From Heyman, C. H. J Bone & Joint Surg. 29 644 1947)

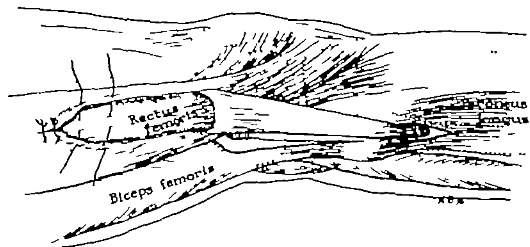


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is not sufficient to be of consequence The procedure is similar in fundamentals to that described by Carrell

Technic (Heyman).—A segment of the peroneus longus tendon of appropriate length and consisting of two-thirds of its thickness is excised according to the method described by Henderson in conjunction with his operation for recurrent dislocation of the shoulder If this muscle is paralyzed, the entire tendon is utilized

A longitudinal incision is made over the medial aspect of the lower end of the femur and continued downward along the medial aspect of the tibia The periosteum of the medial condyle of the femur and of the tibia is incised just posterior to the medial collateral ligament, and the posterior surfaces of the lower end of the femur and the upper end of the tibia are exposed subperiosteally (Fig 952) Holes are drilled through the lower end of the femur proximal to the growth plate and through the upper end of the tibia just distal to the growth plate The drills are directed obliquely their exits being at the posterior aspects of these bones With the knee supported in 150 degrees of flexion, the tendon is passed through the drill holes and the protruding ends are sutured to the anterior margin of the periosteal sheath The tension should be sufficient to make the tendon taut and to resist extension of the knee beyond this position.

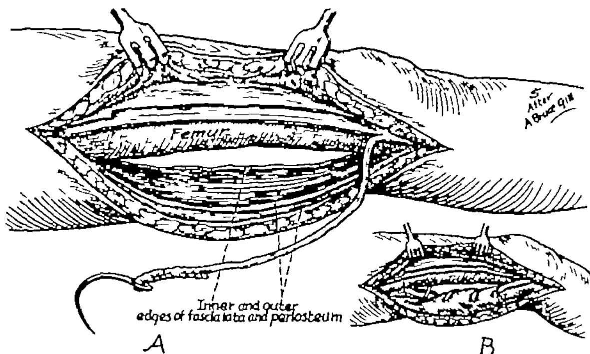


Fig. 953.—Operation on soft structures for genu recurvatum (Gill) Artificial check ligament formed by uniting inner and outer edges of fascia lata and periosteum, thereby reinforcing the posterior structures of the knee which normally limit hyperextension. (Redrawn from Gill, A. B. J Bone & Joint Surg. 13, 49 1931.)

After Treatment.—The extremity is immobilized in a plaster cast from groin to toes with the knee in a position of 150 degrees' flexion. At the end of three weeks, the cast is bivalved and the tension of the posterior structures is estimated. The knee is then replaced in the cast in the original position for an additional three weeks Six weeks postoperatively the cast is removed and physiotherapy is instituted. When extension to 170 degrees is possible a convalescent walking brace which limits extension just short of 180 degrees is fitted and worn for three months

beds by staples *The free ends of the gracilis and semitendinosus tendons* are then sutured to the sartorius muscle, the latter being pulled well backward by means of sutures to the deep fascia (Fig 951) If the procedure has been satisfactorily performed a decided resistance to extension of the knee will be observed and no lateral instability will be present.

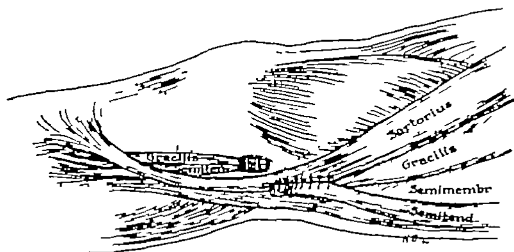


Fig 951.—Gracilis and semitendinosus tendons divided. Ends anchored by staples to medial femoral condyle. Free ends of tendons sutured to sartorius muscle. (From Heyman, C. H. J Bone & Joint Surg. 29 644 1947)

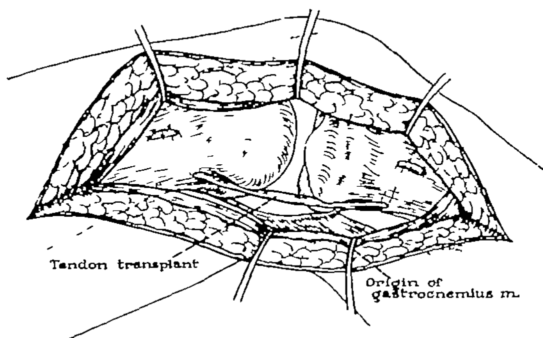


Fig. 952.—Alternat technic if ligament operation (Fig. 949) is inappropriat because of osteoporotic bone. (From Heyman, C. H. J Bone & Joint Surg. 29 644, 1947)

After Treatment.—The knee is immobilized in 110 degrees flexion for a period of eight weeks. Physical therapy is then employed to mobilize the knee, and when extension reaches 170 degrees, the patient is allowed to begin weight bearing in a long leg brace The brace is continued for at least three months.

Because of his failure to anchor the reconstructed ligaments securely in some cases on account of the osteoporotic bone Heyman devised an alternative method of check ligament construction which may be used if lateral instability

is not sufficient to be of consequence The procedure is similar in fundamentals to that described by Carrell

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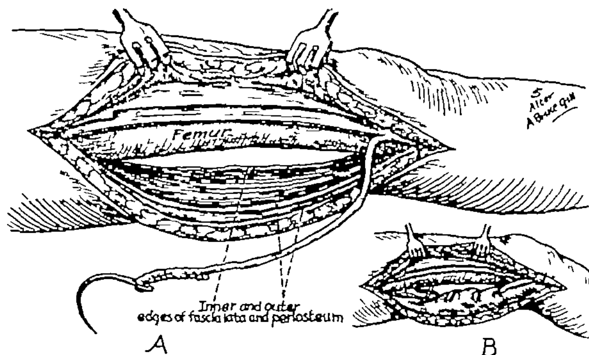


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Technic (Gill).—A lateral longitudinal incision is made from the middle of the thigh to a point just below the head of the fibula. Another incision on the inner aspect is extended from the medial condyle of the tibia to the junction of the middle and lower thirds of the thigh. The fascia lata is incised in line with the skin incisions and the femur is exposed by blunt dissection. The periosteum is split longitudinally to form a posterior one-third and an anterior two-thirds. The posterior flap is stripped from the femur from above downward until it becomes densely adherent to the bone and blends with the posterior lateral ligaments of the knee. The lateral ligaments are divided longitudinally in line with the incisions through the fascia. With an osteotome, the posterior third of the periosteum and the lateral ligament on each side are separated from the condyle of the femur Similarly the detached portion of the lateral ligaments is separated from the upper aspect of the tibia, but is left attached distally one half inch below the line of the knee joint The upper attachment of the posterior ligament of the knee is also separated from the knee together with the periosteum A long strip of fascia lata is removed with its base intact distally This strip serves as a suture with which the posterior free edges of periosteum and fascia lata on both sides are brought together behind the femur while the knee is held in flexion. By this means, the posterior structures are shortened forming a strong check ligament to prevent hyperextension of the knee. The farther downward the suture is carried, the greater is the shortening of the ligament and the degree of limitation of extension of the knee (Fig 953)

After Treatment.—The knee is protected from the strain of hyperextension for a period of at least three months.

Operations for Flail Knee

Arthrodesis

If the knee is unstable in all directions, and if available muscle power is insufficient to warrant tendon transference to overcome this instability the alternatives of permanent use of a long leg brace with a locked knee joint, and arthrodesis remain The knee that is arthrodesed in good position permits a satisfactory gait and in addition, improves the gait by eliminating the weight of the brace On the other hand the disadvantage of a permanently stiff knee, with its attendant inconvenience in sitting should be kept in mind Certain laborers, who present a problem of brace maintenance and in whom the advantages of being free of a brace will outweigh the advantages of being able to sit with a flexed though braced knee will select arthrodesis, while others who sit a great deal will prefer to wear a brace permanently

It has been the policy in this clinic to defer fusion of the knee until the patient is of an age to weigh the advantages and disadvantages of each operation and make his own decision. If both legs are badly paralyzed however one knee may be fused and the other leg stabilized by a brace

In those with gross deformity such as flexion contracture, valgus and external rotation, the extremity should first be placed in the most serviceable position for future use by means of a posterior capsulotomy thus, excessive shortening from excision of bone to correct the deformity is avoided. Arthrodesis may then be undertaken at a second operation. When alignment is normal however or there is only a moderate contracture arthrodesis is carried out without preliminary operation The technic of arthrodesis is described in Chapter XV

OSTEOTOMIES FOR TORSION OF THE TIBIA OR FEMUR

Because of the large number of cases wherein osteotomy is performed for correction of torsion deformities of the tibia or femur following poliomyelitis, this subject is included in the present chapter Primary rotation deformities of the tibia and femur, however, arise not only from infantile paralysis, but also from disturbances in growth as a result of metabolic or infectious disorders, or congenital or static abnormalities of the bones and joints. They may also be secondary to muscle imbalance as observed in spastic paralysis. Internal rotation of the tibia or femur may be associated with congenital dislocation of the hip or varus deformity of the knee, and external rotation of the tibia may be associated with flexion and valgus deformities of the knee or planus and valgus deformities of the foot

Torsion of the Tibia

When torsion of the tibia is associated with deformities, such as varus or valgus, the osteotomy is performed at the point of greatest angulation. The most common site for osteotomy is just distal to the condyles of the tibia, displacement of the fragments is less likely and union more certain if the operation is carried out in this area.

Technic.—An incision one inch in length is made along the crest of the tibia and the soft structures are stripped from the anterior and lateral surfaces. With an osteotome, the bone is completely divided. The fibula is then fractured manually The proximal fragments are held stationary while the distal portions are rotated either externally or internally, as necessary Adduction or abduction deformities are realigned at the same time.

After Treatment.—The knee is flexed to a position of 125 degrees, and a cast is applied from the groin to the toes with the extremity in the corrected position. In the event the patient is obese or the degree of rotational or other deformity has been of major degree, the cast should extend to the crest of the ilium Roentgenograms are made ten days postoperatively to determine whether approximation and alignment at the osteotomy site remain unchanged. Union is usually sufficiently solid by eight weeks after operation to permit weight bearing usually in a protective brace.

Recognizing the difficulty of obtaining the desired degree of rotational correction in the tibia at operation and of maintaining it with accuracy postoperatively O'Donoghue has devised a method of controlled rotation osteotomy of the tibia which has been successfully used in this clinic. Though performance of the procedure requires slightly more time than the ordinary tibial osteotomy, this disadvantage is more than offset by the accuracy of result. The procedure is not advisable however in the presence of an accompanying varus or valgus deformity at the knee of major degree, which must be corrected in addition to the rotation

Technic (O'Donoghue)—Through an anterior longitudinal incision beginning approximately one inch below the tibial tubercle and extending distally four or five inches the tibial shaft is exposed subperiosteally for about three inches through its entire circumference With a motor saw, a linear cut one and one-half to three inches in length is made through the anterior cortex of the tibia paralleling the crest, and about one and one-half inches medial to it. If the bone is small, the posterior soft tissue structures are protected by malleable retractors. If the foot is to be rotated inward the proximal trans-

Technic (Gill) —A lateral longitudinal incision is made from the middle of the thigh to a point just below the head of the fibula. Another incision on the inner aspect is extended from the medial condyle of the tibia to the junction of the middle and lower thirds of the thigh The fascia lata is incised in line with the skin incisions and the femur is exposed by blunt dissection. The periosteum is split longitudinally to form a posterior one-third and an anterior two-thirds. The posterior flap is stripped from the femur from above downward until it becomes densely adherent to the bone and blends with the posterior lateral ligaments of the knee. The lateral ligaments are divided longitudinally in line with the incisions through the fascia. With an osteotome, the posterior third of the periosteum and the lateral ligament on each side are separated from the condyle of the femur Similarly the detached portion of the lateral ligaments is separated from the upper aspect of the tibia but is left attached distally one-half inch below the line of the knee joint. The upper attachment of the posterior ligament of the knee is also separated from the knee together with the periosteum A long strip of fascia lata is removed with its base intact distally This strip serves as a suture with which the posterior free edges of periosteum and fascia lata on both sides are brought together behind the femur while the knee is held in flexion By this means, the posterior structures are shortened, forming a strong check ligament to prevent hyperextension of the knee The farther downward the suture is carried the greater is the shortening of the ligament and the degree of limitation of extension of the knee (Fig 953)

After Treatment.—The knee is protected from the strain of hyperextension for a period of at least three months.

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the incision through the fascia lata is sutured to the posterior periosteal and trochanteric fascial flap thus maintaining the trochanter in the anterior position

A second longitudinal incision four inches in length is then made over the lateral surface of the lower third of the thigh down to the vastus lateralis muscle The intermuscular septum is identified and its anterior surface followed to the shaft of the femur After retraction of the vastus lateralis muscle anteriorly the periosteum is stripped from the lateral surface of the bone just proximal to the metaphysis. The shaft of the femur is then divided with an osteotome and the distal portion of the extremity rotated externally or internally, as indicated A Steinman pin is inserted into the trochanter and incorporated in the cast postoperatively to fix the proximal fragment firmly in the corrected position Usually, the pin may be removed at the end of three or four weeks.

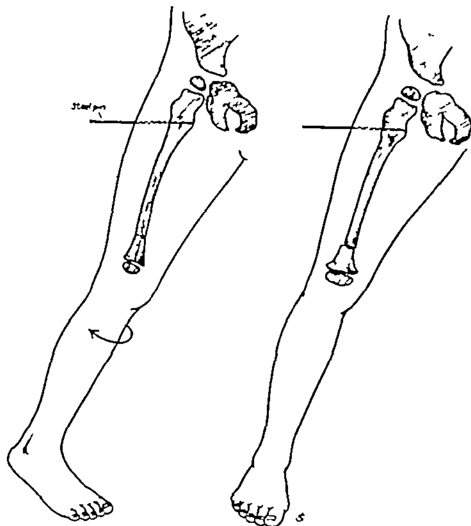


Fig 955.—Supracondylar rotation osteotomy for internal torsion of femur With lower extremity in marked internal rotation, a stainless steel pin is introduced into the greater trochanter to fix the proximal fragment. Femur divided just above condyles, and extremity distal to osteotomy site rotated externally

After Treatment.—A cast is applied from the nipple line to the toes on the affected side and to the knee on the opposite side the knee and lower extremity of the affected side being held in anatomic alignment If union is solid after eight weeks the cast is removed and weight bearing resumed with the aid of a Thomas caliper brace

verse limb of the Z osteotomy is made from the linear cut toward the crest, the distal transverse limb from the linear cut to the medial border If rotation of the foot is to be outward, the proximal cut extends inward the distal cut, outward The cross-cuts are made with an electric saw, osteotome burr or by multiple holes drilled through the cortex A second linear incision is made parallel to the first, the width of the intervening strip of bone being comparable to the desired degree of rotational correction. After removal of this strip the linear osteotomy of the posterior cortex is completed with an osteotome With the posterior cut acting as a hinge the anterior edges of the osteotomy are approximated by rotation Holes are then drilled through the two segments of bone, and fixation secured by catgut sutures or by screws. The periosteum is carefully sutured over the osteotomy site

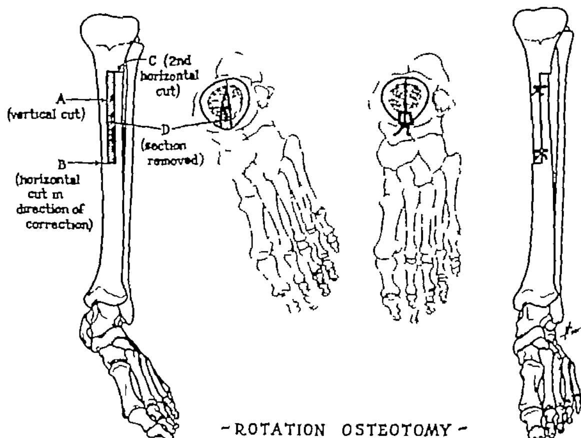


Fig. 954.—O'Donoghue control rotation osteotomy of tibia. Distal horizontal limb of Z-step-cut is always on side of direction of correction. Fixation of osteotomy would be more secure by use of transfixion screws. (From O'Donoghue D. H. South. M. J. 33 1145 1940.)

After Treatment.—A plaster cast is applied from the groin to the toes with the knee in slight flexion The cast is removed after three to six weeks. Usually roentgenograms reveal consolidation of the osteotomy sufficient to permit guarded weight bearing at the end of six weeks.

Torsion of the Femur

Technic (Hoke).—Through a longitudinal incision over the greater trochanter the fascia lata is divided and the vastus lateralis muscle and periosteum stripped from the lateral surface of the bone. With the extremity rotated internally and the trochanter well forward, the anterior margin of

the incision through the fascia lata is sutured to the posterior periosteal and trochanteric fascial flap thus maintaining the trochanter in the anterior position

A second longitudinal incision four inches in length is then made over the lateral surface of the lower third of the thigh down to the vastus lateralis muscle. The intermuscular septum is identified and its anterior surface followed to the shaft of the femur After retraction of the vastus lateralis muscle anteriorly, the periosteum is stripped from the lateral surface of the bone just proximal to the metaphysis The shaft of the femur is then divided with an osteotome and the distal portion of the extremity rotated externally or internally, as indicated A Steinman pin is inserted into the trochanter and incorporated in the cast postoperatively to fix the proximal fragment firmly in the corrected position Usually, the pin may be removed at the end of three or four weeks

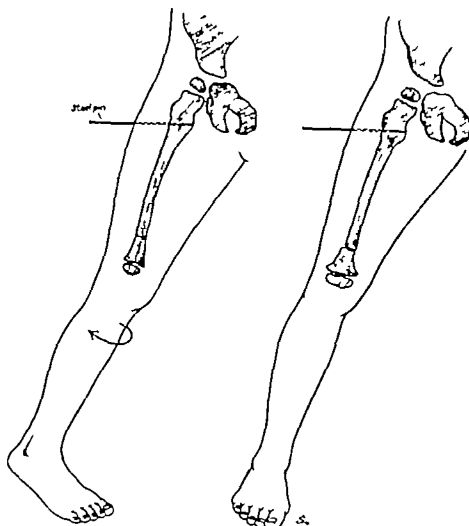


Fig. 656—Supracondylar rotation osteotomy for internal torsion of femur With lower extremity in marked internal rotation a stainless steel pin is introduced into the greater trochanter to fix the proximal fragment. Femur divided just above condyles, and extremity distal to osteotomy site rotated externally

After Treatment.—A cast is applied from the nipple line to the toes on the affected side and to the knee on the opposite side, the knee and lower extremity of the affected side being held in anatomic alignment. If union is solid after eight weeks, the cast is removed and weight bearing resumed with the aid of a Thomas caliper brace

Because of the small area of apposition of the fragments and the possibility of displacement or malalignment following transverse osteotomy, Haas has devised a procedure based upon the following principle If a series of longitudinal osteotomies are made about the circumference of the bone, the structure will be so weakened as to yield in any direction to bending or twisting forces, yet its continuity will be undisturbed

Technic (Haas) —*After exposure of the osteotomy site, the periosteum* is completely reflected from each side of the bone. A longitudinal cut 3 to 4 cm. in length is then made through the entire thickness of the cortex. On each side of the first cut, at a distance of approximately 1 cm., parallel cuts of the same length are made Additional and similar cuts are then made at intervals of 1 cm around the remainder of the circumference. A total of five or six usually suffices. Haas states that when force is applied, a green stick fracture is created in each unit. Similarly, when torsion force is applied, the units respond by rotating like the strands of a piece of rope.

HIP

Deformities associated with paralysis of the muscles of the hip are extremely disabling The most common deformity is abduction contracture, which may or may not be associated with varying degrees of flexion and external rotation. Less often flexion with adduction and internal rotation is observed. In bilateral contractures, locomotion is possible only as a quadruped. Correction of the deformities will allow the patient to assume an upright posture

DEFORMING INFLUENCE OF ILIOTIBIAL BAND

The predominant role of the iliotibial band as a deforming factor in the lower trunk and lower extremity following poliomyelitis involving these regions has received comparatively little attention. Yount, in 1926 observed that the iliotibial band was responsible for a triad of deformities, i.e., hip flexion and abduction contracture knee flexion contracture, and genu valgum. Forbes also wrote on this subject. C E. Irwin, in a personal communication (1948) has elaborated upon Yount's original postulates to show that an almost insignificant contracture of the iliotibial band may be responsible for a tremendous number of undesirable sequelae in the lower trunk and the lower extremities. Believing that Irwin's unpublished data is extremely important, we give his opinions in detail, according him full credit for the subsequent information in this section.

Anatomy —One must recognize the expanse of the fascia lata (the iliotibial band is a thickened portion of the fascia lata) to appreciate its deforming possibilities. Proximally the fascia lata arises from the coccyx sacrum crest of the ilium and as far anteriorly as Poupart's ligament and the ramus of the pubis. Either the superficial or the deep layer of the fascia is attached to most of the gluteus maximus and all of the tensor fasciae femoris muscles. All of the appendages converge to form the iliotibial band on the lateral aspect of the thigh in this location, the band is continuous with the lateral intramuscular septum and therefore is attached to the linea aspera throughout its length. Distally the origin of the short head of the biceps further contributes to its dynamic possibilities. The insertion of the iliotibial band includes all the prominences below the lateral aspect of the knee. Because of its anatomic location in a plane anterior and lateral to the axis of the hip, and posterior

and lateral to the axis of the knee the iliotibial band is in an advantageous position to produce disability through spasm of the biceps gluteus maximus, or tensor fascia femoris muscles.

Deformities From Contracture of Iliotibial Band

In the acute stage of poliomyelitis treatment should be directed toward preservation of the full length of the iliotibial band as evidenced by a complete range of passive motion of the hip and knee without pain or discomfort. If this status is not attained any or all of the following deformities may ensue.

Flexion, Abduction, and External Rotation Contracture of the Hip.—A flexion and abduction deformity of the hip is readily attributable to contracture of the iliotibial band since this structure lies lateral and anterior to the hip joint The position of external rotation is assumed as a matter of comfort If this position is allowed to remain however, the rotators of the hip contract secondarily thus contributing the third component of the deformity

Genu Valgum and Flexion Contracture of Knee.—As growth progresses the iliotibial band with its firm attachment to the linea aspera serves as a taut bowstring across the knee joint, gradually abducting and flexing the tibia on the femur As the deformity increases, the band lying posterior and lateral to the joint, gains a mechanical advantage which produces a vicious cycle.

Discrepancy in Length.—Irwin believes that the taut fascial structure attached to the femur throughout its length can in a measure hold in check the growth of both femoral epiphyses and the upper tibial epiphysis Regardless of the cause clinical information corroborates the impression that a taut iliotibial band on one side is likely to be associated with considerable discrepancy in length of the lower extremities over a period of years of growth.

External Torsion of Tibia With or Without Subluxation of Knee Joint.—The lateral attachment of the iliotibial band particularly in the presence of an active strong short head of the biceps gradually rotates the tibia and fibula on the femur Once the deformity becomes extreme the tibial condyle subluxates on the external condyle of the femur until the head of the fibula comes to lie in the popliteal space.

Secondary Equinovarus Deformity of Foot.—In the presence of external torsion of the tibia the ankle joint and knee joint no longer remain in the same planes. By the use of an improperly fitted brace which does not compensate for this external torsion, the foot will assume a varus position. If allowed to remain, adaptive changes become fixed and require surgical correction. The prophylaxis of the foot deformity consists of adjustment of the brace to the externally rotated position.

External Torsion of the Femur.—In long standing flexion abduction contractures, the head and neck of the femur assume an anteverted position, similar to that in congenital dislocation of the hip i.e. with the patella forward the trochanter lies posteriorly

Pelvic Obliquity.—If the patient is in a supine position and the hip is maintained in abduction and flexion the pelvis may be held at a right angle to the longitudinal axis of the spine (Fig 956) When the patient stands, however and the extremity is brought downward for weight bearing i.e parallel to the vertical axis of the trunk the pelvis must assume an oblique position the crest of the ilium is low on the contracted side and high on the opposite side. The lateral thrust forces the pelvis toward the unaffected

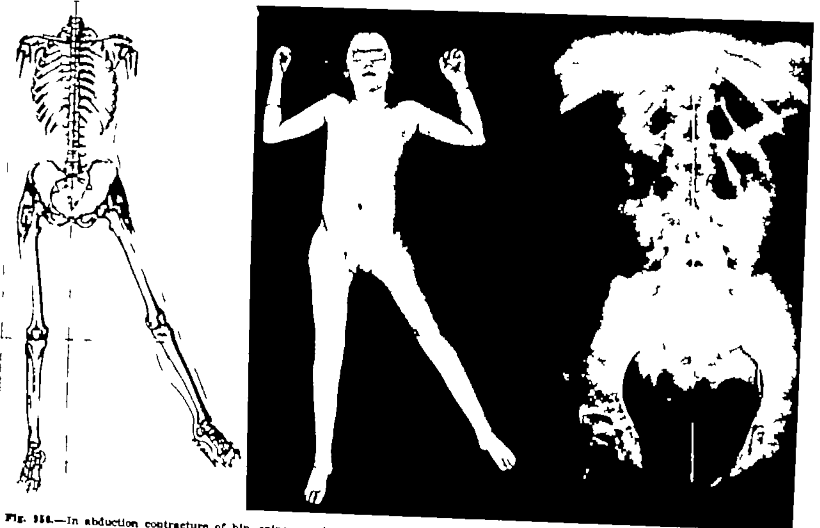


Fig. 956.—In abduction contracture of hip, spine remains straight and pelvis is level so long as hip is maintained in abducted position. (Courtesy of Dr C. D. Irwin.)



Fig. 857.—Same as Fig. 856. When abducted hip is forced into weight bearing position, pelvis is forced into oblique position with secondary scoliosis of lumbar spine. (Courtesy of Dr G. L. Irwin.)

side. Further, the trunk muscles on the affected side are lengthened and those of the opposite side become contracted. *The two contralateral contractures, viz., abduction contracture on the affected side and shortening of the trunk muscles on the unaffected side if not corrected, hold the pelvis in an oblique position until skeletal changes fix the deformity* (Fig 957)

Increased Lumbar Lordosis.—*A bilateral flexion contracture of the hip* causes the pelvis to rock forward In order that the trunk may assume an upright position the patient develops a compensatory increase in the lumbar lordosis.



Fig. 958.—Following correction of flexion abduction contracture of right hip, two long leg casts are applied, incorporating skeletal traction on well leg side. *With right hip in flexion* and abduction, sufficient traction is applied to well leg to level pelvis. (Courtesy of Dr C. E. Irwin.)

Surgical Treatment

Irwin emphasizes this point, *with which we agree* A contracture of the iliotibial band, regardless of the age of the patient or the duration of the deformity cannot be adequately corrected by conservative measures. Attempts at correction by traction increase the obliquity and hyperextended position of the pelvis, and do not exert any material corrective *influence on the primary* deformity

In early contractures the Soutter operation or the Campbell transference of the crest of the ilium are contraindicated, in that (1) contracture of the rectus femoris iliopsoas gluteus medius and minimus muscles are late adaptive contractures (2) release of the proximal component of the iliotibial band from the ilium corrects only one of the elements, allowing the other muscular forces to continue undisturbed through the intact portion of the iliotibial band On the other hand, early contractures may be satisfactorily corrected by division of the iliotibial band distally together with the lateral intermuscular septum as suggested by Yount



Fig. 939 —With spine flat and pelvis level, well leg side incorporated into single-spica cast, locking this segment in as a unit. Right hip still in abduction and flexion. (Courtesy of Dr C. E. Irwin.)

In flexion abduction contracture of the hip of long standing division of the iliotibial band must be supplemented by the Campbell transference of the crest of the ilium or the Soutter fasciotomy

Division of Iliotibial Band and Lateral Intermuscular Septum (Yount) — See p 1032

After Treatment (Irwin) —A Kirschner wire is inserted into the femur of the normal leg just above the condyles. Long leg casts are applied incor

porting the skeletal traction on the unaffected side With the affected thigh in flexion and abduction and sufficient traction on the normal leg to place the pelvis at a right angle to the vertical axis of the trunk a plaster cast is applied to the trunk incorporating the long leg cast on the unaffected side to form a single spica *The affected extremity is now internally rotated ex* tended, and adducted to the point of resistance. The cast is then completed to form a double spica extending from the nipple line to the toes on both sides.



Fig. 940—Extremity on operated side is adducted and extended up to point of resistance. Double-spica cast is then completed. Subsequent corrections obtained by further wedging involved extremity into extension and adduction. (Courtesy of Dr C. E. Irwin.)

Every three to five days thereafter correction is increased by further wedging By proceeding in this manner in contrast to well leg traction correction of abduction and flexion contractures is accomplished simultaneously beginning with the pelvis level and the lumbar spine flat. The anterior tilting of the pelvis and the *exaggerated lumbar lordosis are thus avoided.*

Transference of the crest of the ilium was devised by Campbell especially for extreme flexion and abduction deformities of the hip following poliomyelitis. Briefly the procedure consists of division of the anterior superior

spine with the attached sartorius muscle and of the outer margin of the crest of the ilium with the attachment of the gluteal and *tensor fasciae femoris* muscles. The latter are stripped subperiosteally from the outer table of the ilium to permit extension of the hip Tenotomy of the iliopsoas tendon and origin of the rectus femoris muscle with capsulotomy of the hip may be necessary in extreme flexion deformity The anterior superior spine and the detached gluteal muscles are reattached at a lower level This procedure and others for the correction of deformities of the hip joint are described in detail in the chapter on Ankylosis and Deformity

TENDON TRANSFERENCE

One of the most severe disabilities from poliomyelitis is that incident to paralysis of either the gluteus maximus or medius muscles, or of both The result is an instability of the hip and an unsightly and fatiguing limp In paralysis of the gluteus medius muscle the trunk sways toward the affected

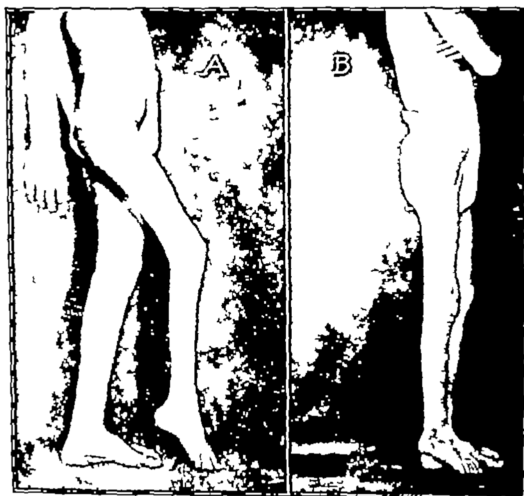


Fig. 881.—*A*, Flexion contracture of hip and paralytic drop foot. *B* After transference of crest of ilium, triple arthrodesis, and bone block. Discrepancy in length of extremities compensated f r by an elevation.

side and the opposite side of the pelvis sags. When the gluteus maximus muscle is paralyzed weight bearing on the affected side causes the body to lurch backward. The stamina of the gluteal muscles may be demonstrated by the Trendelenburg sign When a normal individual bears weight on one extremity and flexes the other at the hip, the pelvis is held in a horizontal plane

and both gluteal folds are on the same level. If the gluteal muscles are impaired and weight is borne on the affected side the pelvis on the normal side will drop below the level of the affected side. In extensive paralysis the test cannot be carried out, as the patient is unable to balance himself on the disabled extremity

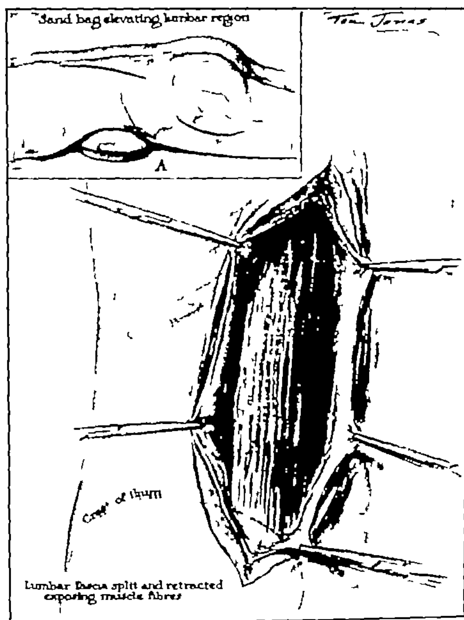


Fig. 862.—Kreuscher method of transference of erector spinae muscle for paralysis of gluteus maximus and medius muscles. Exposure of erector spinae muscle. Dotted line indicates incision through muscle and line of detachment of tendinous insertion on crest of ilium. A Insert showing skin incisions. (From Kreuscher P H: Surg. Gynec. 40: 591, 1925.)

Obviously in these circumstances, surgery offers the only hope of an improvement in function, as any apparatus is inadequate for maintaining stability of the pelvis. Stabilization is accomplished, when feasible, by the transference of muscular attachments to replace the action of the gluteal muscles.

Fritz Lange, of Munich, first utilized the erector spinae muscle for stabilizing the pelvis. He lengthened this structure with silk sufficiently to permit its insertion into the greater trochanter Kreuscher's technic is almost identi

cal Ober and Hey Groves improved these procedures by connecting the erector spinae muscle with the trochanter by a strip of fascia lata also utilizing the tensor fasciae femoris muscle Dickson devised an operation for paralysis of the gluteus maximus and medius muscles wherein the origin of the tensor fasciae femoris muscle is transferred from the anterior third of the wing of the ilium to the posterior third Legg follows a somewhat similar

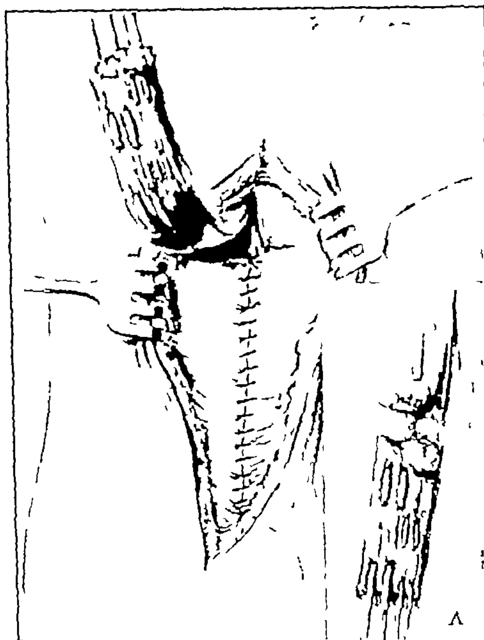


Fig. 961.—Same as Fig. 962. Portion of muscle to be transferred dissected from its bed. Lumbar fascia closed, with transverse incision to avoid constriction of pedicle of muscle. Insert illustrates method of placing fascial sutures into muscle, small pads of fat being inserted beneath end loops to prevent pressure necrosis. Loops at two different levels and each stitch placed on alternating strips of muscle. (From Kreuscher P H. Surg. Gynec. Obst. 49: 593 1926.)

technic for paralysis of the gluteus medius muscle alone, namely transference of the tensor fasciae femoris muscle from the anterior third to the middle third of the crest of the ilium Wagner and Rizzo have described a procedure embodying the use of the anterior thigh muscles their origin being transferred posteriorly

Transference of Erector Spinae Muscle for Paralysis of Gluteus Maximus and Medius Muscles

Kreuscher lists the advantages of transference of the erector spinae muscle as follows (1) traction is in a direct line, (2) the muscle acts synergistically with the gluteal muscles, and (3) the normal erector spinae motion is not disturbed When added power of abduction of the hip is needed, any of the following procedures utilizing the erector spinae muscle may be supplemented by the Legg operation

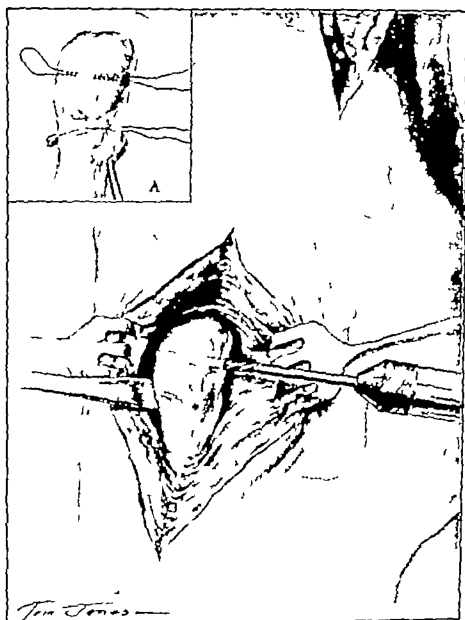


Fig. 964—Same as Fig 962. Greater trochanter and portion of shaft exposed. Hole drilled from behind forward through trochanter Insert show loop of silkworm gut through hole in trochanter to facilitate passage of silk cords. A large aneurysm needle carries strands of silk around shaft of femur just above lesser trochanter (From Kreuscher P H.: Surg. Gynec. Obst. 40: 593 1925.)

Technic (Lange) —A longitudinal incision is made on the outer side of the erector spinae muscle, the sheath is incised, and the muscle freed for a distance of four to five inches from its distal end The sheath is now sutured

beneath the muscle to provide a free gliding bed Numerous fascial sutures are threaded into the distal end of the muscle Half of the sutures are fixed to the lesser trochanter by means of a drill hole, or to the femur below the greater trochanter posteriorly These serve to replace the gluteus maximus muscle The other half are fastened subperiosteally or through a drill hole in the greater trochanter as substitutes for the gluteus medius and minimus

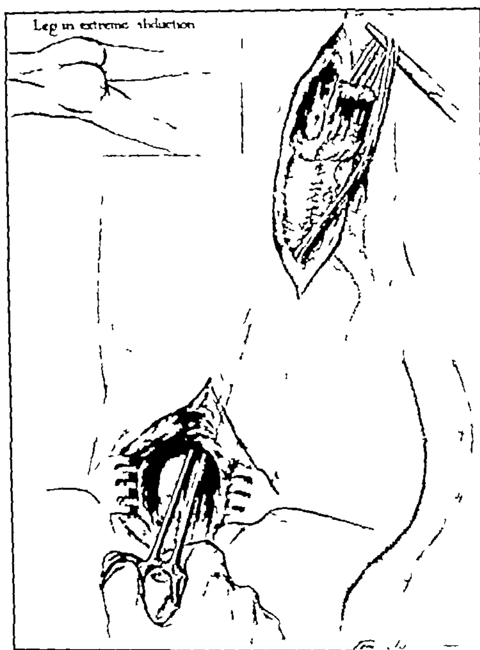


Fig. 865.—Same as Fig. 862. Fascial sutures passed subcutaneously from lumbar incision to trochanteric incision. Insert shows position of hip in extreme abduction when ligatures are tied. (From Kreuscher P H. Surg. Gynec. Obst. 40: 593, 1925.)

muscles. Similarly the latissimus dorsi of the opposite side may be brought over for replacement of the paralyzed gluteus medius and minimus muscles. At the point where the fascial cords cross the spinous processes and the ilium Lange lays a strip of fascia lata beneath the muscles.

After Treatment.—The patient is placed in a double spica cast with the hip in hyperextension. After six weeks, this position is maintained by a splint

for an additional three or four months. Physical therapy is then initiated to strengthen and develop the transplant to the fullest degree.

Technic (Kreuscher).—With the patient in the prone position, an incision eight inches long is made over the *lower portion of the erector spinae muscle*, beginning at the posterior crest of the ilium and continuing in the longitudinal axis of the muscle. After opening the sheath the outer half of the

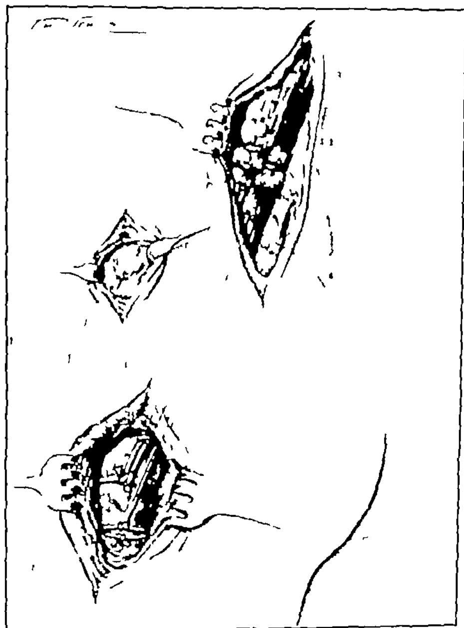


Fig. 966.—Same as Fig. 962. Fascial sutures tied under moderate tension. Rectangular piece of fascia lata affords a smooth gliding surface over crest of ilium for transferred muscle. Through an additional incision over crest of ilium, another cord of fascia is attached to periosteum of iliac crest above and to tip of greater trochanter below (From Kreuscher P H. Surg. Gynec. Obst. 40 502, 1925.)

erector spinae muscle is detached from the crest of the ilium, *dissected out of* the sheath for a distance of six inches, and the sheath is closed. Two groups of fascial sutures each containing four strands are placed in the prepared stump of the muscle from above downward, with care to protect the nerve and blood supply The sutures should be of sufficient length to reach well

below the trochanter A second short curved incision its convexity anteriorly exposes the greater trochanter and the upper portion of the shaft of the femur By means of a 12-inch forceps, the sutures on the end of the erector spinae muscle are grasped and drawn through a subcutaneous tunnel from the first incision to the second Two of the four sutures are inserted into a hole drilled through the greater trochanter, the other two are passed around the shaft of the femur just above the lesser trochanter With the hip in extreme abduction and extension, the sutures are tied in such a manner as to place the erector spinae muscle under adequate tension. To provide a smooth gliding surface a piece of fascia lata one and one half by two and one half inches is sutured over the posterior aspect of the crest of the ilium immediately above the trochanter Through a separate small incision two additional fascial sutures are attached to the crest of the ilium and passed subcutaneously to the greater trochanter to aid in abduction of the leg

After Treatment.—The hip is immobilized for a period of eight weeks in extreme abduction and extension by means of a double spica cast. During this time, the patient is encouraged to practice abduction of the hip in the cast. On removal of the cast physical therapy is instituted over the entire extremity and mild electrical stimulation is applied over the erector spinae muscle for the purpose of strengthening and developing it to the fullest degree, the hip being immobilized between exercise periods in an abduction splint The splint is worn for at least six months, that the silk may become securely attached and thus withstand subsequent strain. The patient is then permitted to walk with the aid of crutches.

Transference of Erector Spinae and Tensor Fasciae Femoris Muscles for Paralysis of Gluteus Medius and Maximus

In 1927 Ober and Hey Groves independently described almost identical procedures, combining the principles of the Lange or Kreuscher and the Legg operations.

Technic (Ober).—A skin incision is made from the level of the first lumbar vertebra to the posterior superior iliac spine one inch lateral to the spinous processes, exposing the deep fascia and muscles of the back. The lower five or six inches of the erector spinae muscle are mobilized as follows The muscle is stripped longitudinally in the line of cleavage one half inch lateral to the spinous processes of the last three or four vertebrae. Dissection is then carried downward, freeing the tendinous portion of the muscle from the sacrum and posterior crest of the ilium. The entire muscle is separated along the lateral intermuscular septum throughout its depth, down to the transverse processes, and upward as far as the perforate dorsal nerves.

Another incision is made over the lateral aspect of the thigh from the level of the tip of the trochanter to one inch above the patella. A long strip of fascia lata one and one half inches wide is dissected free up to and including a portion of the fibers of the tensor fasciae femoris muscle A tunnel is created in the muscle and periosteum two inches below the base of the trochanter and the free end of the flap passed proximally through this tunnel from before backward Anteriorly the fascial strip is firmly sutured at the entrance of the tunnel, and posteriorly is sutured to the gluteus maximus muscle. The new tendon is drawn under the gluteal fascia to the lower angle of the first incision and its end is scarified. The free end of the erector spinae

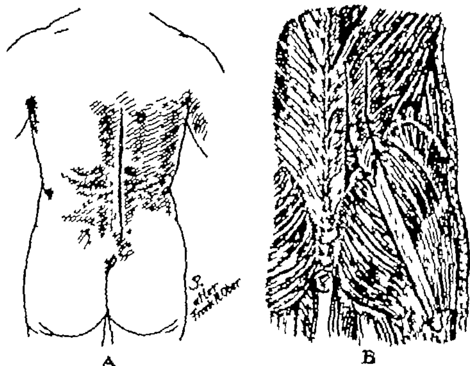


Fig. 947.—Transference of erector spinae and tensor fasciae femoris for paralysis of gluteus medius and maximus muscles (Ober). *A*, Skin incision from first lumbar vertebra to posterior superior iliac spine one inch lateral to midline, for exposure of erector spinae muscle. *B*, Outer half of erector spinae group detached and sutured to fascia lata. (Redrawn from Ober, F. R.: J. A. M. A. 88: 1063, 1927.)

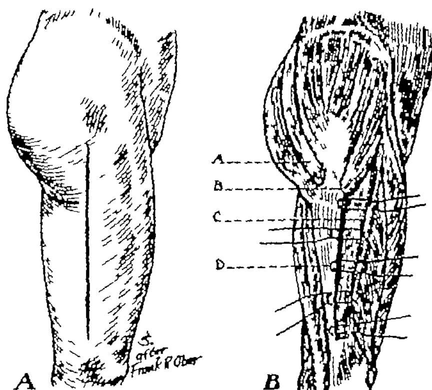


Fig. 948.—Same as Fig. 947. *A*, Incision on lateral surface of thigh from trochanter to one inch above patella, exposing fascia lata and tensor fasciae femoris muscle. *B*, Long flap of fascia lata, 1½ inches wide, has been dissected free from the thigh up to and including fibers of tensor fasciae femoris muscle. (*A*) Flap passed from above backward, beneath muscle and periosteum two inches below base of trochanter, (*B*) and firmly sutured at entrance anteriorly and to gluteus maximus tendon posteriorly. Defects in fascia (*C*) and (*D*) closed with mattress sutures. (Redrawn from Ober, F. R.: J. A. M. A. 88: 1063, 1927.)

muscle is overlapped on the scarified area of the fascial flap for at least two or three inches. The edges of the flap and the aponeurosis of the muscle are then united under moderate tension.

After Treatment.—The extremity is immobilized in a plaster spica cast for three weeks. The cast is then bivalved and exercises are begun to increase the power in the transferred muscle.

Transference of Tensor Fasciae Femoris Muscle for Weakness of the Gluteus Maximus and Medius

Since the tensor fasciae femoris is a small muscle, incapable of assuming fully the action of paralyzed gluteus maximus and medius muscles, little improvement in function has been observed following its transference. The use of this muscle should therefore be reserved for patients who exhibit a weakness, rather than complete paralysis, of the gluteus medius and maximus muscles.

Technic (Dickson).—With the patient on the side, the incision is begun at the anterior superior spine and extended along the crest of the ilium to the posterior superior spine. Anteriorly the incision is prolonged onto the thigh a distance of four inches, passing along the medial border of the tensor fasciae femoris muscle. The lateral edge of the incision is reflected backward, exposing the fascia covering the tensor fasciae femoris and gluteal muscles. The tensor fasciae femoris is separated from the sartorius and rectus femoris muscles anteriorly for four to five inches, and from the gluteus medius muscle for three inches. Care should be taken not to disturb the nerve supply which emerges from beneath the gluteus medius at its lower third and passes into the under surface of the tensor fasciae femoris muscle. By means of a chisel, the origin of the tensor fasciae femoris is separated with a portion of the crest of the ilium. The atrophied gluteus medius muscle is now lifted and the severed origin of the tensor fasciae femoris muscle passed beneath it to emerge through an incision which has been made obliquely upward and backward toward the posterior superior spine in the fascia along the anterior border of the gluteus maximus muscle. The tunnel beneath the gluteus medius should be near its insertion into the greater trochanter that the transferred muscle may pass as far posteriorly as possible in a direct line. With the hip in extreme abduction the bone adherent to the origin of the tensor fasciae femoris muscle is fixed in a groove in the crest of the ilium adjacent to the posterior superior spine, No. 3 chromic catgut being used for this purpose. The posterior edge of the transplanted muscle is firmly sutured to the under surface of the gluteus maximus muscle.

After Treatment.—The extremity is held in extreme abduction and placed in a single spica cast. After three weeks the cast is bivalved and exercises are begun. At the end of six to eight weeks the cast is removed entirely and the extremity allowed gradually to resume its normal position.

Transference of Tensor Fasciae Femoris Muscle for Weakness of the Gluteus Medius Muscle

Legg has devised a technic for strengthening the abductor power of the hip by utilizing the tensor fasciae femoris muscle. In his first operation, described in 1923, the iliotibial band was transferred into the lateral aspect of the femur. Subsequently he modified the procedure by transferring the

origin of the tensor fasciae femoris muscle to the middle third of the crest of the ilium directly above the trochanter This structure is not sufficiently powerful to restore normal active abduction when the gluteus medius muscle is completely paralyzed although the gait will be materially improved by its transference. Legg states that if a fair amount of power is left in the gluteus medius, transference of the tensor fasciae femoris muscle will often eliminate the abductor limp

Technic (Legg) —Beginning posterior to the middle third of the crest *of the ilium an incision is carried forward to the anterior superior spine,* thence downward along the medial border of the tensor fasciae femoris muscle to the middle third of the thigh

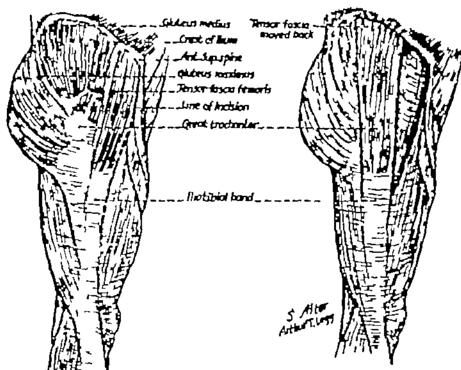


Fig. 869.—Transference of tensor fasciae femoris for weakness of gluteus medius muscle (Legg) *A* Line of incision and normal anatomy about hip joint. *B* Origin of tensor fascia femoris detached and transferred posteriorly (Redrawn from Legg, A. T New England J Med. 209: 61, 1933.)

The tensor fasciae femoris is separated from the sartorius muscle and dissection is continued distally along the anterior border of the iliotibial band The origin of the tensor fasciae femoris muscle is now detached from the anterior crest of the ilium together with a portion of the cartilage of the crest, and the posterior border of the muscle is freed from the greater trochanter The muscle may then be displaced posteriorly over the trochanter The hip is held in abduction and with No 18 silk the origin of the tensor fasciae femoris muscle is secured to the crest of the ilium in a direct line above the greater trochanter

After Treatment.—To maintain the position of abduction the extremity is immobilized in a bivalved spica cast which has been made previously After twelve days, muscle training is instituted. At the end of six weeks the patient is allowed to walk with support by an abduction hip brace Usually the brace is removed at the end of three months.

Transference of Anterior Muscles of Thigh for Paralysis of Gluteus Medius and Weakness of Gluteus Maximus Muscles

Wagner and Rizzo have utilized three muscles from the anterior surface of the thigh the tensor fasciae femoris, the sartorius, and the long head of the rectus femoris. These authors state that the diverse directional pull of these muscles tends to hold the head of the femur in its proper position and increase the stability of the hip joint

Technic (Wagner and Rizzo).—The incision is begun at the posterior inferior spine carried around the crest of the ilium to the anterior superior spine *thence curved backward across the trochanter* The tensor fasciae femoris and sartorius muscles are freed at their origin with a part of their bony attachments, and elevated distally by blunt dissection The origin of the rectus femoris muscle, which is thus exposed, is detached freed as far distally as possible then sutured to the tensor fasciae femoris and sartorius muscles. The three muscles are next transferred posteriorly through a tunnnel beneath the paralyzed gluteus medius muscle and the anterior border of the gluteus maximus. *With the hip in extreme abduction and hyperextension, the transferred* muscles are then displaced as far posteriorly as possible at this point, a small window is created on the wing of the ilium usually in the region of the posterior inferior spine and the conjoined muscles are fixed into this space by sutures passed through the bone.

After Treatment.—The after treatment is similar to that described previously Muscle re-education is begun four to five weeks after operation.

These measures are only relatively successful. In complete paralysis of the gluteal muscles, normal balance is never restored and the gluteal limp remains, though it is perhaps improved In partial paralysis, however tendon transference may materially improve the gait.

STABILIZATION OF THE HIP JOINT

In the presence of extensive paralysis about the hip joint particularly if the gluteus medius and maximus muscles are involved complete or partial dislocations are common. The problem is more difficult than that encountered in congenital dislocation. As a rule, the dislocation may be easily reduced the difficulty lies in maintaining reduction, since there is frequently a coxa valga deformity as well as a shallow acetabulum

Shelf Operations

When *subluxation is associated* with partial paralysis, treatment may consist of shelf operations combined with transference of active muscles to replace the lost power of the abductors and extensors of the hip These shelf operations differ from those described for congenital dislocation of the hip in that reconstruction of the acetabulum must be more extensive in order to maintain reduction a large bony abutment must be created above anterior and posterior to the head of the femur since the muscle power which normally aids *in stabilizing the hip joint is no longer adequate* It should be remembered that the shelf operation will not eliminate the hip lurch incident to weakness of the abductor and extensor muscles, but will only improve the gait by stabilizing the hip in its socket and thus abolishing subluxation or dislocation on weight-bearing

Campbell has devised a shelf operation especially for dislocation of the hip associated with infantile paralysis.

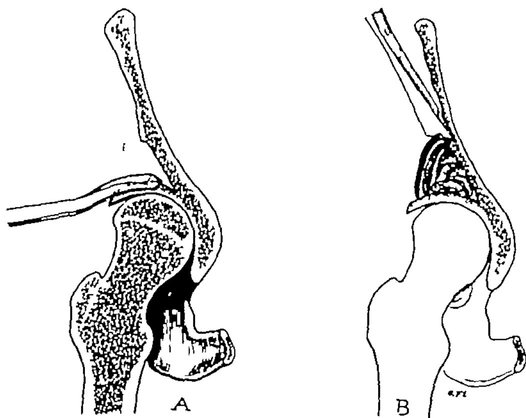


Fig. 970.—Shelf operation for paralytic dislocation of the hip (Campbell). *A*, Curved chisel driven into ilium [illegible] inch above acetabulum, following contour of its roof. Entire articular surface then levered outward and downward. *B*, Defect filled with chips and shavings from wing of ilium.

Fig. 971.—*A*, Paralytic dislocation of hip. *B*, After Campbell shelf operation.

Technic (Campbell).—Open reduction is accomplished by a method similar to that described by Galloway (p 1604) or Kidner (p 1605) A large curved gouge or chisel (Fig 970 A) is driven into the ilium three-eighths inch above the acetabulum, following the contour of its roof This large section of bone is then levered downward and outward forming a cap over the reduced head of the femur To hold the new acetabular rim in position, cancellous bone from the ilium is packed into the gap thus formed and numerous small flaps and slivers of bone are turned downward onto the shelf Overlapping of the capsule aids in maintaining reduction

After Treatment.—While traction is exerted by an assistant bands of adhesive tape are attached to the thigh and a double spica cast is applied from the nipple line to the ankle on the affected side and to the knee on the normal side Ten to fifteen pounds of weight are attached to the adhesive and continued for four weeks. The cast is then bivalved and the anterior half discarded. Passive movements are carried out for two weeks, the traction being resumed after exercise periods. After six weeks, the posterior half of the cast is also discarded and the patient is placed on a bed with a firm surface Physical therapy is then instituted At eight weeks postoperatively, the patient is allowed to walk with crutches and to bear weight cautiously with the leg supported by a Thomas caliper brace

Other shelf operations are described in Chapter XXV

Arthrodesis

Arthrodesis provides complete stability of the hip and improves the gait since the loss of power in the extensors and abductors of the hip is compensated for by the elimination of the hip motion If arthrodesis is to be performed however the stability of the ligaments should be fairly strong at the knee good power in either the hamstrings or gastrocnemius is also helpful since the elimination of hip motion imposes an increased strain on the knee The effect of arthrodesis of the hip upon the knee is in many respects similar to that of a pantalar arthrodesis in the ankle

In the paralytic subluxation or dislocation of the hip the use of some form of internal fixation is necessary to prevent recurrence of the subluxation or dislocation during the healing phase In this clinic Knowles and Moore pins have been employed with success.

Schanz Osteotomy

Irwin has employed the Schanz subtrochanteric osteotomy (p 1398) in fixed pelvic obliquity provided the deformity cannot be corrected by the usual measures for flexion abduction contracture of the hip, or by the Lowman or Mayer fascial procedures (p 1400) He also utilizes this method in certain cases of severe unilateral weakness of the gluteus medius muscles (p 1399) We have had no experience with this operation in paralysis of the muscles about the hip joint (see below)

PELVIS AND SPINE

The deforming and crippling possibilities following involvement of the muscles of the trunk, pelvis, and hips present an extremely complicated study in kinesiology A mere perusal of the operative technics for paralysis in these regions will be of little benefit to the reader unless he has a true understanding

of the normal. Irwin describes the action of the hip abductors and lateral trunk muscles in the normal individual under conditions of weight bearing as follows

The various weight bearing components, i.e., the different muscle groups, bone levers and weight bearing thrusts, have a symmetrical triangular relationship as illustrated in Figs. 972-974 The double line BC represents the abductor muscles of the hip The single line AB is the head neck, and trochanter which provide a lever for function of the abductor muscles. The broken line AC represents the direction of force superimposed upon the femoral head. The

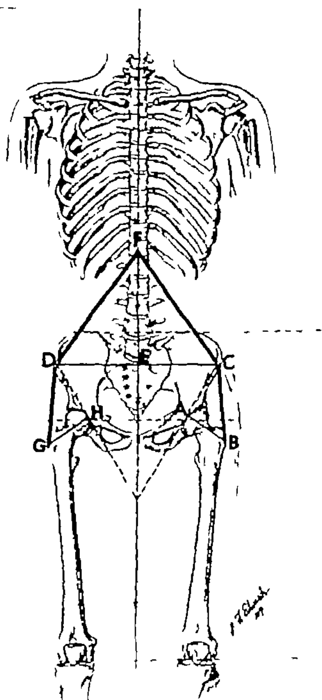


Fig. 973.—Normal balanced skeleton. (From Irwin, C. E. J. A. M. A. 133 231, 1947.)

lateral trunk muscles are represented by lines *DF* and *FC*. The pelvis is the bony lever *DF* upon which the trunk muscles exert their effort. The line *FE* is the center of gravity of the line of weight bearing above the pelvis. In the balanced skeleton the triangles above and below the pelvis are symmetrical.

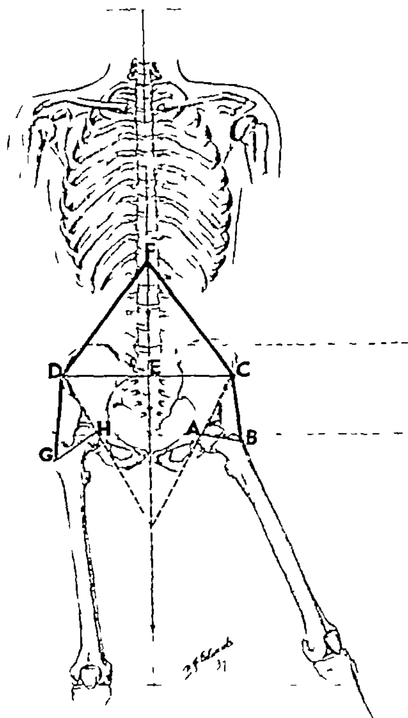


Fig. 973.—Majority of true, fixed pelvic obliquities are initiated by contractures below iliac crest. See text for details. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)

In normal walking the abductors of the hip pull downward on the weight bearing side of the pelvis, while the lateral trunk muscles on the opposite side pull upward, maintaining the pelvis at a right angle to the vertical axis of the

trunk The femoral head on the weight bearing side serves as the fulcrum, or pivoting point. The point of fixation of the trunk muscles, i e., the ribs and spine, is less stable than that of the abductor muscles. When *DF* elevates the pelvis, *FC* must provide counter fixation *FC* depends upon the abductors of

Fig 874.—Abnormal mechanical relationships created when contracted hip is brought down into weight-bearing position. See text for details. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)

the hip *BC* for further counter fixation. Thus, with each step the femur on the weight bearing side is still the central point of action for this coordinated fixation and counter fixation It is therefore obvious that each system is dependent upon the other for proper pelvic balance during walking

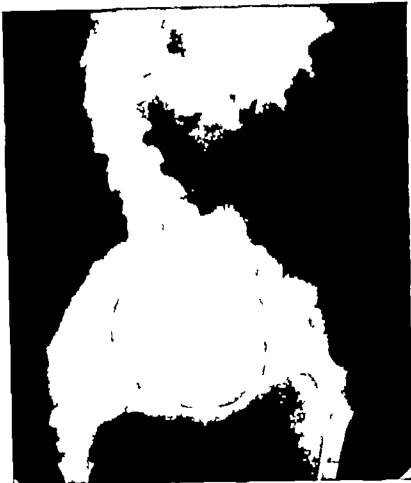


Fig. 975.—Fixed pelvic obliquity causes difficulty in walking from patient's inability to stand on adducted extremity and bring opposite or abducted extremity forward. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)



Fig. 976.—Same as Fig. 975 after subtrochanteric osteotomy. Femur has now been shifted nearer midline into a more efficient and useful weight bearing position. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)

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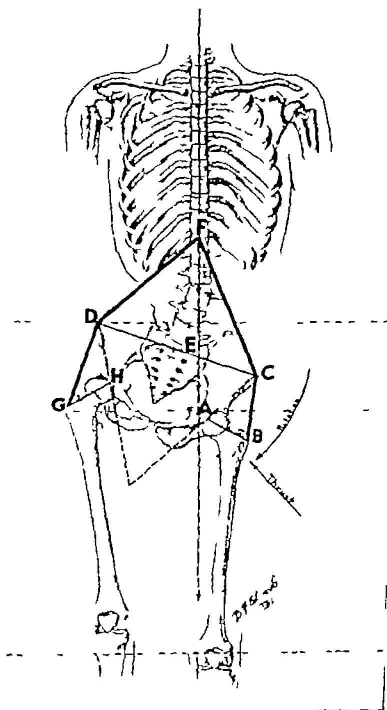


Fig. 974.—Abnormal mechanical relationships created when contracted hip is brought own into weight bearing position. See text for details. (From Irwin, C. E. J. A. M. A. 3: 231, 1947.)

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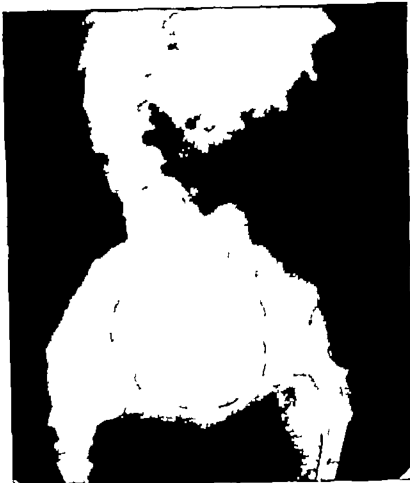


Fig. 975.—Fixed pelvic obliquity causes difficulty in walking, from patient's inability to stand on adducted extremity and bring opposite or abducted extremity forward. (From Irwin, C. E. J. A. M. A. 133: 231, 1947.)



Fig. 976.—Same as Fig. 975 after subtrochanteric osteotomy. Femur has now been shifted nearer midline into a more efficient and useful weight-bearing position. (From Irwin, C. E. J. A. M. A. 133: 231, 1947.)

In abduction contracture of the hip the line BC is shortened, thus preventing the patient from walking normally. As the abducted extremity is brought down in a weight bearing position the femur acting through the contracted abductor group BC depresses the pelvis on the affected side. In this motion, the affected extremity and the pelvis act as a unit; the pelvis is displaced by a lateral thrust toward the opposite side, thereby disturbing the normal symmetry of the pelvis in relation to the center of gravity. The weight bearing thrust from above FE now closely approaches the affected hip. Theoretically the adducted position elongates the abductor muscles DG to the same degree that the abductors BC have become shortened. Even though the muscles are normal the contractility and efficiency of the abductors DG are diminished.



Fig. 977.—Fixed pelvic obliquity with severe deformity. Spine has been fused with pelvis in a position which permits weight of superstructure to fall in a plane lateral to both femoral heads. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)

With the pelvis in an oblique position, the vertical weight bearing thrust of the trunk now passes practically through the hip joint on the depressed side, increasing the demands upon the already weakened abductors DG. In turn the trunk muscles are affected by this disturbance in symmetry. The lateral trunk muscles, FC, become elongated and the efficiency of their contractility is commensurately impaired. The elongation of the abductors DG interferes with the interrelation of the muscles as a means of providing a fixed point for contracture of the lateral trunk muscles FC. The lattter though normally elevating the pelvis on the depressed side are now placed in a position which prevents efficient function. Finally the lever EC has been shortened, placing the trunk muscles at a mechanical disadvantage. The consequent deformity leads to a disruption

of the mechanics of walking. If the contracted lateral trunk muscles on the normal side and the abductors on the affected side hold the pelvis in this oblique position for a sufficiently long time, the deformity becomes fixed through adaptive skeletal changes in the spine.

This deformity, in association with paralysis of the legs severe enough to warrant the use of two long braces, causes difficulty in walking. If the



Fig. 978.—Same as Fig. 977. Osteotomy has been carried out at junction of middle and upper thirds of femur, thereby creating a neck out of entire upper one-third of shaft. Femur has now been shifted into a position lateral to weight-bearing line of superstructure. (From Irwin, C. E.: J. A. M. A. 133: 231, 1947.)

quadriceps on the apparently long extremity is strong the brace may be unlocked to permit flexion at the knee the patient may then be able to walk, though with a pronounced limp Without a brace, the patient must widely abduct the affected extremity in order to take a step, otherwise, all the weight is borne on the 'long' extremity while the opposite one becomes more or less useless.

In the presence of severe unilateral paralysis of the abductor muscles, DG essentially the same mechanical factors prevail i e. with weight bearing on the affected side the opposite pelvis assumes a depressed position thus interfering with balance, and with bringing the opposite leg forward in walking

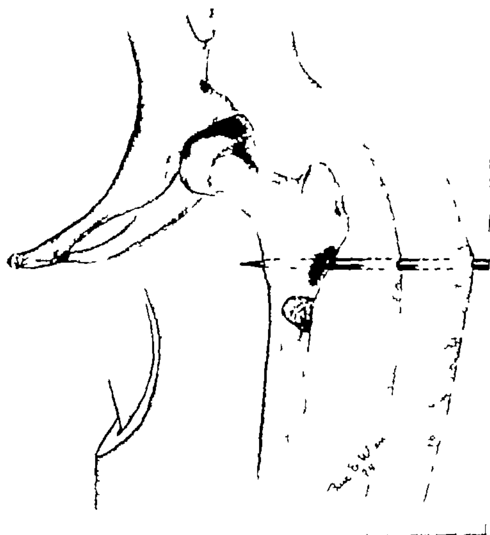


Fig. 979—Irwin subtrochanteric osteotomy U-shaped segment of bone removed just below greater trochanter Segment cut into chips and replaced in defect. Steinman pin inserted at right angle just proximal to osteotomy site. (From Irwin, C. E.: J A. M A. 133: 231, 1947)

Treatment *of* Pelvic Obliquity

Irwin feels that the majority of pelvic obliquities are initiated by contractures below the iliac crest and that relatively few arise from inequality in the strength of the abdominal and lateral muscle groups. If no contractures are present below the iliac crest, the obliquity of the pelvis should be considered as secondary to scoliosis, rather than a true pelvic obliquity

The rather insignificant early origin of pelvic obliquity has been previously discussed (p 1372) Before skeletal fixation of the deformity takes place, pelvic obliquity may be treated by correction of the hip deformity (p 1376) or by the Lowman or Mayer procedures, described below

Before undertaking subtrochanteric osteotomy one should be certain that the obliquity of the pelvis and the lumbar scoliosis are fixed This may be readily determined by roentgenograms of the lumbar spine, as demonstrated in Figs. 956 and 957



Fig. [illegible].—Same as Fig. [illegible] Four weeks after first stage, osteotomy is completed by manual osteoclasis, new callus acting as hinge. Proximal fragment held in position by Steinman pin incorporated in cast. Subsequently, defect in cast is repaired. Steinman pin removed at six weeks. (From Irwin, C. E. J. A. M. A. 133: 231, 1947)

Assuming that the pelvis cannot be restored to a functional position Irwin suggests shifting of the weight of the adducted femur i e the so-called short side nearer the center of gravity by an osteotomy and displacement of the fragments medially in a valgus relationship toward the midline of the pelvis. Severe unilateral gluteus medius weakness may be treated in a similar manner By this procedure a patient who had previously been unable to walk, may

become able to do so (Figs 975 and 976) If the pelvic tilt is extreme and the head of the femur on the abducted side i e the so-called long leg is practically within the center of gravity (Fig 977), an osteotomy is carried out at the middle and upper thirds of the femur the distal fragment being adducted to form a varus relationship at the osteotomy (Fig 978)

Technic (Irwin) —Through a lateral longitudinal incision the subtrochanteric region of the femur is exposed A Steinman pin is inserted through both cortices just proximal to the level of the contemplated osteotomy A U shaped section of bone is removed from the lateral aspect of the femur through approximately one-half the thickness of the bone The bone wedge is then cut into small sections and replaced in the defect. A double spica cast is applied and left intact for four weeks At this time a wedge with its base laterally is cut through the cast The remaining medial cortex of the femur is fractured manually and the leg is abducted to the desired degree callus at the site of the previous operation serves as a hinge and permits green-sticking so the fragments never separate The defect in the cast is completed with plaster The Steinman pin is removed at the end of six weeks. As a rule, the osteotomy site is firmly united within ten or twelve weeks.

ABDOMEN, TRUNK, AND SHOULDER GIRDLE

The disability produced by paralysis of the muscles of the abdomen, trunk and shoulder girdle has long been recognized, yet until 1932 treatment consisted entirely of muscle re-education physical therapy support by apparatus, and fusion of the spine for scoliosis. Lowman deserves a great deal of credit for taking the lead in this field and suggesting surgical measures to compensate for the loss of activity of these muscles. Frank Dickson and Mayer also made contributions to the subject

Since that time, studies of end results have been reported by Eaton and Irwin and by Williamson Moe and Basom These papers confirm the value of fascial transplantation in reducing abdominal lordosis and localized abdominal bulging improving the gait as a result of pelvic stabilization, improving bowel and bladder expulsive function, decreasing fatigue and increasing the general comfort of the patient. It should be pointed out, however that before abdominal or lateral iliocostal fascial transplantation, existing muscle function should be carefully investigated in order that the fascial transplants may be correctly placed to compensate properly for the paralysis present and any deformities of either the spine, pelvis, or about the hips may be detected and corrected prior to fascial transplantation.

Mayer believes that the fascial graft not only hypertrophies with use, but also grows with the patient in his patients who were followed from early childhood to late adolescence he observed a measurable lengthening of the fascial strip as the distance from the rib to the iliac crest has increased.

Patients who are suitable subjects for fascial transplantation may be divided into two groups those who have a bilateral or generalized abdominal weakness, and those with a predominantly unilateral muscle weakness in the latter the abdominal imbalance may have given rise to a pelvic obliquity or even a fixed scoliosis.

Pelvic obliquity itself does not necessarily arise from abdominal imbalance or a fixed scoliosis rather it may follow a fixed abduction or adduction hip

contracture, or an abduction contracture of one hip and an adduction contracture of the opposite hip This of course will result in a functional lengthening of one leg though the discrepancy is merely apparent and not real The latter type of obliquity is discussed above

Lowman's conclusions as to the asymmetrical influence of faulty kinetics are as follows

1 Weakness or paralysis of the rectus abdominis produces an anterior tilt of the pelvis and an increased lumbar lordosis, which is exaggerated by active flexors of the hip

2 Muscle imbalance of the quadratus lumborum produces a lateral deviation or pelvic obliquity, with secondary compensatory changes above. The latissimus dorsi may produce a similar effect.

3 The active pull of the serratus anterior and the pectoralis major in the presence of droop shoulder and weak rhomboids throws the weight of the shoulder down against the thoracic wall anterior to the angle of the ribs and has a flattening influence on the side of the chest wall

4 Contracture of unopposed muscles with diagonal or lateral pull such as the transversalis, serratus anterior and abdominal obliques, together with the asymmetrical action of the unbalanced pull exerted by the pectoralis latissimus dorsi and quadratus lumborum contribute materially to spinal and costal deformities and distortions of a rotary and lateral type.

Frank Dickson has carried these observations a step farther noting the relations of paralysis of various muscles of the shoulder girdle to paralytic scoliosis of the cervical and upper dorsal spine droop shoulder asymmetry of the shoulders, deformity of the chest and instability of the shoulder girdle

The first difficulty in the treatment of paralysis of the muscles of the trunk lies in determining the muscle or muscle groups involved and their relative power Lowman has devised certain tests by which this may be accomplished

Recti raising the head against resistance

Recti and obliques in relation to flexors of the hip straight leg raising

Transversalis and obliques starting to roll over

Oblique fixation with the patient supine extending the arm upward in the form of a V and half abducting the legs, the opposite arm and leg are raised.

The quadratus lumborum and to a lesser degree, the latissimus dorsi shifting the pelvis upward and downward in the lateral plane thereby alternately shortening and lengthening the relative length of each leg against resistance Mayer's test for the action of the quadratus lumborum is as follows With the patient in the supine position the surgeon grasps both ankles and instructs the patient to pull up first one side of the pelvis and then the other The quadratus muscles are not alone concerned in this movement, of course by palpation of the quadratus muscles during the manouver however much can be learned about their relative strength

Mayer employs the following test to determine the power of the lateral abdominal muscles the patient in the supine position clasps the examiner around the neck with both hands, lifting the trunk clear of the table The examiner flexes the patient's body toward the side, then requests the patient to swing the body back to the natural position as he palpates the lateral abdominal muscles.

The activity of the abdominal muscles may also be determined by Beevor's sign: shifting of the umbilicus proximally, distally, or to one side or the other when the abdominal muscles are on tension, as in walking or when the head is raised against resistance.

Limited areas of weakness may be defined as follows: the patient takes a deep breath and presses down on the diaphragm in an attempt to balloon the abdomen. In total paralysis, the abdomen will be greatly distended, and tonicity of the abdominal muscles will be lost. If only part of the muscles are weakened, the abdomen in this area will protrude to a greater distance than the surrounding area, and resistance of the wall over the affected region is commensurately diminished.

The strength of the serratus anterior muscle may be determined by a straight arm push.

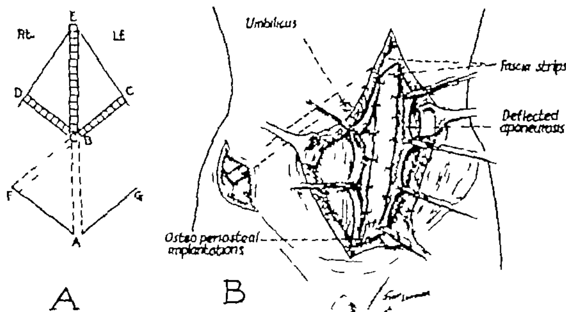


Fig. 981.—Fascial transplant for paralysis of lower recti and right oblique muscles (Technic of Lowman). A, Dotted lines indicate proposed site of transplant for paralyzed muscles, in relation to active upper abdominal muscles. B, Strip of fascia lata in sheath of left rectus attached above to active muscles and below through osteoperiosteal tunnel raised from pubic bone. Second strip attached to upper rectus at same location as first strip, passed subcutaneously downward and outward to right ilium, and anchored through osteoperiosteal tunnel with pelvis tilted upward on right side. (Redrawn from Lowman, C. L.: J. Bone & Joint Surg. 14: 763, 1932.)

To quote from Frank Dickson: "The determination of weakness in other muscles—the quadratus lumborum, the latissimus dorsi, the serratus anterior, the rhomboidei, and at times the trapezius—is not so readily made and requires much study, and then one is not always sure. In our experience, the reason for this lies in the difficulty of isolating the action of these muscles because of their intricate and complex relationship in function with each other and with other muscle groups. However, it has seemed from our examinations that weakness in all of the muscles mentioned has been a factor in the production of deformity or of interference with function in some cases."

Detailed discussions of the methods of determining the strength of the various abdominal and back muscles are to be found in the Kendalls' monograph, as well as in "Muscle Testing" by Daniels, Williams and Worthingham.

Fascial Transplantation for Paralysis of the Abdominal Muscles

Fascial Transplantation for Paralysis of Lower Recti and Oblique Muscles

Technic (Lowman)—An incision is made in the midline of the abdomen from two inches above the umbilicus to the symphysis, exposing the aponeurosis of the rectus muscles. The sheath is opened and reflected exposing the paralyzed lower half of the muscles At the same time assistants remove a strip of fascia lata one inch wide and nine inches long from the thigh The fascia lata is transplanted into the left rectus muscle, from the lower two inches of the active upper portion to the symphysis. The proximal end of the strip is fixed to the upper rectus by silk sutures. The distal end is inserted through an osteoperiosteal tunnel raised from the pubic bone With the operating table dipped in the middle to decrease tension on the abdominal wall the umbilical stem is grasped and pulled distally as far as possible The lower end of the fascial strip is then firmly sutured to itself with silk Similarly sutures are placed on each side of the strip at intervals of one to one and one-half inches.

A second incision is made along the crest of the ilium at the anterior superior spine Another fascial strip is then sutured to the upper rectus at the same location as the first and passed subcutaneously in the fat downward and outward to the right ilium at the point of attachment of Poupart s ligament. This strip is fixed to the ilium through an osteoperiosteal tunnel and with the right side of the pelvis tilted upward to remove all slack from the upper left oblique muscles is sutured to itself under tension

After Treatment.—The patient remains in a semirecumbent position for three weeks. Sitting in a chair may then be permitted Lowman recommends early movements in the water as a means of beginning re-education and tension on the new tendons without undue strain of gravity This is started at twenty-one to twenty four days postoperatively and gradually increased

Any combination of fascial strips may be used to treat any distribution of abdominal paralysis they may be implanted in the upper half of the abdomen or the lower or may extend from the sternum to the symphysis and from a rib margin to the opposite ilium in the region of the anterior superior spine

Lowman has modified his original procedure wherein the rectus aponeurosis was opened in order that the fascial strip might be laid in flat He has found that fascia tends to rope up and for this reason now inserts both north and south and oblique strips subcutaneously

The fascial strips are attached to the ilium and pubis by being passed through a hole in the bone and sutured upon themselves with interrupted sutures of nonabsorbable material The costal attachment should be made by exposing the rib subperiosteally roughening its surface with an osteotome and suturing the fascia to the adjacent soft tissues and periosteum It has been found that if the fascial strip is passed around the rib the fascia may tear the rib from the cartilage This is especially true in young children

In attaching fascia to the rectus muscle near the umbilicus the old technic of laying back a flap of the aponeurosis and spreading out the terminal inch of the fascial strip is still utilized The fascia is fixed to the rectus with interrupted nonabsorbable sutures, and the aponeurotic flap is placed over it and reattached

For paralysis of the entire abdominal wall transplants are placed in crisscross manner from the costal margin to the opposite ilium If lordosis is too

severe, another strip is dropped from the intersection of the two strips to the symphysis.

At the Children s Hospital in Baltimore, the fascial strips are left attached to the upper aspect of the thigh if the transplant is to run from one or both ilia, a subcutaneous tunnel is made over the iliac crest for this purpose. In the event a complex type of transplantation is necessary, particularly if fascia is to be removed from both thighs, the procedure is carried out in two stages.

Occasionally in the paralysis of quadratus lumborum and externus abdominis obliquus muscles, Lowman still employs a transplant from the lateral costal margin to the lateral crest of the ilium to assist in providing lateral stability and to prevent the lateral sag which makes the leg too long functionally

If the entire abdomen requires support Mayer attaches fascial grafts at least four inches wide to the outer half of Poupart s ligament as well as to the iliac crest The upper half of these grafts is slit longitudinally so as to form two tails The medial tail is attached as closely as possible to the ensiform cartilage and to the cartilage of the ninth rib while the lateral tail is attached to the rib itself

Fascial Transplantation for Paralytic Pelvic Obliquity

For stabilizing the pelvis and reinforcing the abdominal wall, Mayer has modified Lowman s procedure by extending a fascial transplant from the ninth rib to the iliac crest and outer portion of Poupart s ligament.

Technic (Mayer) —A transverse incision four inches in length is made along the course of the ninth rib from the anterior axillary line to the sternum,

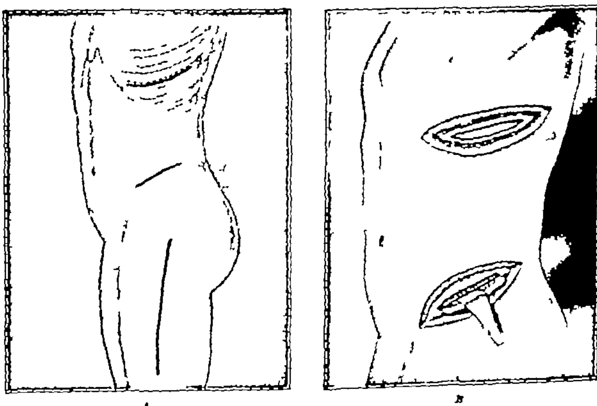
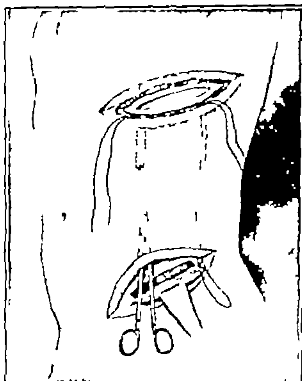


Fig 952.—Mayer technic of fascial transplantation. *A* Incisions for removal and insertion of fascial graft. *B*, Exposure of ninth rib and iliac crest. (From Mayer L. : J Bone & Joint Surg 26: 257 1944.)

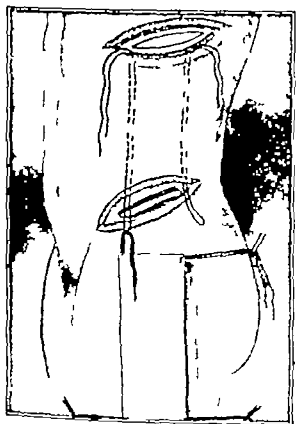


A.

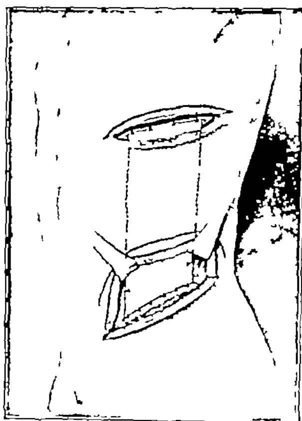


B.

Fig. 933.—Same as Fig. 93. A Tunnel three inches wide created to connect iliac crest and ninth rib. B Passage of guide suture through tunnel. (From Mayer L. J Bone & Joint Surg. 26: 5 1944.)



A



B

Fig. 934.—Same as Fig. 932. A Sheet of fascia prior to passage through tunnel by guide sutures. B Fascial transplant in place, fastened under tension to iliac crest and ninth rib. Lateral sutures through abdominal musculature holding fascial transplant in position. (From Mayer L. J Bone & Joint Surg. 26 257 1944.)

and the rib is *denuded of periosteum* A *silk guide suture is passed about* the rib and a loop is left projecting from the lower surface The fascia in the region of the sternum is split for a distance of two inches to allow attachment *of the inner tail of the fascial graft* A second incision four inches long is *made from a point three inches posterior to the anterior superior spine* to the middle of Poupart s ligament. The crest of the ilium is split off for a distance of three inches, forming an osteoperiosteal flap to which the fascia lata remains attached The two incisions are then connected by a sub*cutaneous tunnel at least three inches* wide throughout its extent. Two guide sutures are passed through this tunnel one on the medial the other on the lateral side A third incision is made the entire length of the thigh, and a strip of fascia lata three inches wide and sufficiently long to reach from the *crest of the ilium to the ninth rib* is removed One end of the strip is fastened to the iliac crest and Poupart's ligament by a series of No 1 chromic catgut sutures. A *second series of sutures fixes the osteoperiosteal flap into its* original location The other end of the strip is then split to form two tails, one for the rib attachment and the other for the sternal attachment. The strip is passed upward through the subcutaneous tunnel by means of traction sutures, being so held as to lie flat within the tunnel. The lateral half of the upper end of the fascial transplant is drawn about the rib by means of the guide suture placed during the first step in the operation The ribs and pelvis on the affected side are approximated so far as possible by tilting the pelvis upward and bending the body laterally and the strip around the rib is sutured to itself under tension. The medial tail of the strip is fixed to the fascia near the sternum The fascial transplant is spread as wide as possible and attached to the abdominal muscles by additional sutures along its margin

If the entire abdominal wall does not require such great support, Mayer uses a three-inch strip of fascia extending from the crest of the ilium to the ninth rib (Figs 982 984)

Fascial Transplantation for Paralysis of Quadratus Lumborum Muscle

For paralysis of the quadratus lumborum muscle Frank Dickson passes a fascial strip from a bony attachment at the posterior and middle thirds of the crest of the ilium upward subcutaneously and inserts the proximal end into the sacrospinalis muscle at the level of the twelfth dorsal or first lumbar vertebra.

Technic (Dickson) —A four inch longitudinal incision is made two inches lateral to the spine its center at the level of the twelfth dorsal vertebra. The sheath of the sacrospinalis muscle is incised and retracted A transplant of fascia lata ten inches long and two inches wide is removed from the thigh, looped through a mass of the sacrospinalis muscle approximately one-*half* inch in diameter and sutured to the muscle at two or three places over a length of one to three inches. The sutures should not be placed in the sheath, but rather directly in the muscle fibers. The sheath is then resutured over the transplant except at the point of its exit. A subcutaneous tunnel is made to the wing of the ilium as far laterally [illegible] At this point, a transverse incision is made along the crest of th[illegible] [illegible]d a slot formed in the bone by means of a drill and rongeur Th[illegible] [illegible]n plant is then passed subcutaneously from [illegible] [illegible]rst to the second [illegible] [illegible]oped through the bone, and

sutured to itself under tension with silk In making this transplant, the fascial strip must be fastened first to the muscle or active end and then to the bone or fixed end

Fascial Transplantation for Paralytic Scoliosis

It has not definitely been proved that abdominal fascial transplant alone will prevent later development of a paralytic scoliosis though Eaton has used it in patients in the stage of recovery who despite continued recumbency are developing a scoliosis. These patients may later become candidates for spine fusion if the scoliosis progresses after fascial transplantations In any event abdominal function will be improved even though fusion of the spine becomes necessary

Should there be a question as to whether the fascial operation alone will satisfactorily control a developing scoliosis it is Mayer s policy to perform the fascial operation first observing the patient for a period of six months and taking roentgenograms at three month intervals if the scoliotic curve increases 10 degrees during this time a spinal fusion is performed



Fig 985.—Fascial transplant for paralysis of quadratus lumborum muscle (Dickson) Proximal end of tran plant inserted into erector spinae muscle and passed subcutaneously as far laterally as possible anchored to crest of ilium through slot in bone. (Redrawn from Dickson, F D J Bone & Joint Surg. 19 405, 1937)

Other than in the use of fascial transplants to replace paralyzed muscles of the trunk, abdomen and shoulder girdle, the surgical treatment of paralytic scoliosis does not differ materially from that described in the chapter on Static Deformities (p 1516)

Frank Dickson has devised a procedure for a particularly difficult form of paralytic scoliosis, namely high cervicothoracic curvature with a droop shoulder from paralysis of the scapular elevator and spinal muscles. The procedure is designed to elevate the depressed shoulder girdle and provide a fixator action against the pull of the unparalyzed muscles on the convex side of the cervical curve To accomplish these objectives, he employs two fascial strips, one from the spine of the scapula to the cervical muscles on the con cave side of the curve the second from the spine of the scapula to the spinous process of the first thoracic vertebra.

Technic (Dickson).—*A curved incision four inches in length* is made along the spine of the scapula well outward toward its acromial end, and a slot is created through the spine. The cervical fascia is exposed through a second incision extending from the spine of the scapula to the apex of the cervical curve on *its concave side. A strip of fascia is next* removed from the *thigh and, with the gliding surface outward,* its edges are sutured together with fine catgut, forming a tube One end of the tube is laced into the cervical muscles at the apex of the curve on the concave side. The *depressed shoulder* is elevated as far as possible and the other end of the tube is passed through the slot in the spine of the scapula and sutured in place with silk

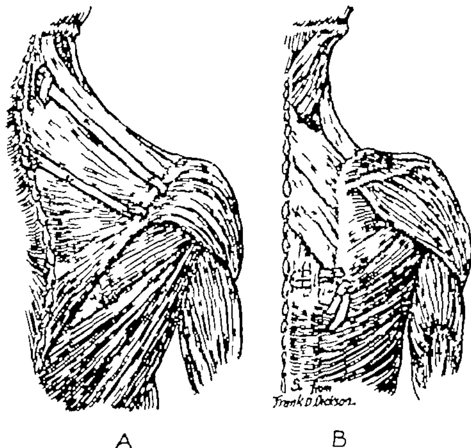


Fig. 816.—A Fascial transplant for high cervicothoracic scoliosis with droop shoulder (Dickson) *a* Fascial strip from spine of scapula to cervical muscles. *b*, Fascial strip from spine of scapula to spinous process of first thoracic vertebra. *B* Fascial transplant for unopposed serratus anterior muscle Strips passed from slots in vertebral border of scapula into the *spinal muscles and into the latissimus dorsi* muscle. (*Redrawn* from Dickson, F D. J Bone & Joint Surg 19 40 1937)

An incision is then made over the spinous process of the first thoracic vertebra, and a hole is drilled through the base of the spine. A second fascial strip is looped through a second slot formed at the vertebral end of the spine of the scapula, passed subcutaneously to the spinous process of the first thoracic vertebra, through the hole, and sutured to itself under tension

After Treatment.—*The arm is maintained in 135 to 130 degrees abduction* by means of a cast or by attachment to the head of the bed. Exercises are begun at the end of three weeks, and usually all support is removed five or six weeks postoperatively Dickson states that the shoulders have remained elevated to a satisfactory degree without support and further the scoliosis of the cervical spine has not increased *Neck pain and fatigue are also less* severe.

Henry, in 1927 performed a similar operation on a patient with paralysis of the trapezius muscle and winging of the left scapula Two fascial slings were utilized The first was inserted through a hole drilled in the medial border of the scapula just above the spine then looped about the spinous process of the sixth cervical vertebra deep to the interspinous ligament The second strip of fascia lata was passed through a hole two and one half inches below the first thence around the spinous process of the third dorsal vertebra

Fascial Transplantation for Paralysis of the Scapular Muscles

Paralysis of the scapular muscles results in considerable instability of the scapula, inefficient function of the shoulder and indirectly may be responsible for high thoracic or cervicothoracic curves The following measures are designed to obviate these disabilities

Fascial Transplantation for Paralysis of the Serratus Anterior Muscle

The purpose of this transplant is to prevent movement of the scapula toward the vertebral column Theoretically by attaching the fascial transplant to the pectoralis major muscle some active anterior pull on the scapula may be secured

Technic (Dickson) —With the scapula held as far forward as possible i.e., in approximately the position desired after the transplant is completed an incision three inches in length is made longitudinally over its inferior angle By means of a drill and a small rongeur a hole is cut completely through the scapula. A second incision of similiar length is made over the lateral chest wall just below the pectoralis major muscle as it leaves its origin on the ribs. These two incisions are connected by a subcutaneous channel The fascial transplant is looped through the inferior border of the pectoralis major muscle and sutured to itself and to the muscle fibers, thence through the subcutaneous channel to the inferior border of the scapula With tension on the transplant and the scapula in the desired position, the end of the strip is drawn through the hole in the scapula and sutured to itself

Fascial Transplantation for Unopposed Serratus Anterior Muscle

In the presence of weak rhomboidei and levator scapulae muscles, and an active serratus anterior muscle the scapula moves toward the axilla, the upper vertebral border being tilted inward and downward with abduction of the shoulder The serratus anterior muscle arises on the upper eight or nine ribs anteriorly passes around the chest wall beneath the scapula, and is inserted along its entire vertebral border The rhomboidei and levator scapulae muscles, which are antagonists to the serratus anterior muscle arise from the upper four dorsal and cervical vertebrae pass obliquely downward and outward and are inserted on the superficial side of the vertebral border of the scapula thus, necessarily they pull the scapula medially and upward and rotate the inferior angle in a similar direction The scapula is stabilized by a fascial transplant passed from a slot in its vertebral border inward and slightly downward, and laced at the distal end into the spinal muscles a second strip is passed downward and slightly medial into the latissimus dorsi.

Technic (Dickson) —Four small incisions are utilized for inserting the two transplants. For the first a short vertical incision is made over the spinal muscles opposite the vertebral border of the scapula. Through a similar incision, the vertebral border of the scapula is exposed and a small slot created through the bone just above the inferior angle. The two incisions are con

nected by a subcutaneous channel A fascial transplant is fixed through the slot in the scapula and passed subcutaneously to the second incision in a slightly medial and downward direction The medial end of the transplant is looped through the spinal muscles and sutured to itself under tension, or if desired is drawn through a hole in the vertebral spinous process at the level of the vertebral angle of the scapula

If this procedure is used alone elevation of the arm will produce a rotary movement centering about the transplant. The inferior angle must therefore be secured by means of a transplant extending medially and below to the latissimus dorsi muscle For this purpose a small vertical incision is made over the inferior angle of the scapula and a slot is created through the bone. Two or three inches below and medial to this point the latissimus dorsi is exposed by an incision of similar size Frequently little if any actual muscle is present in the latissimus dorsi sheath in this region. If so the transplant may be carried directly into the spinal muscles with equal success, only an additional small vertebral incision being necessary To complete the operation the fascial transplant is looped through either the latissimus dorsi or spinal muscles, passed subcutaneously to the first incision, and, under tension fixed through the slot in the inferior angle of the scapula (See Fig. 986B)

Fascial transplants for paralysis of the trunk, abdomen, and shoulder girdle are still in the experimental stage No large series of end results have as yet been reported although Frank Dickson has employed the plastic repair operations rather extensively One may anticipate improvement in general health improvement in function and endurance of the lower extremities on walking stabilization of the pelvis, and possibly prevention of deformities and distortions of the trunk The scapula can be definitely stabilized with a commensurate improvement in function of the shoulder The early results which Dickson has observed are sufficiently gratifying to stimulate further study of this complex subject.

Paralytic Scoliosis

The prevention and treatment of paralytic scoliosis is one of the most difficult problems with which the orthopedic surgeon is confronted The deformity may develop even as the patient is being kept recumbent in the subacute phase of the disease, or later after walking has been resumed.

All patients with paralysis of the trunk should have a minimum of six months recumbency Colonna and Vom Saal have noted an increased incidence of scoliosis in those patients treated with an inadequate period of recumbency They too have noted the development of scoliosis after the cessation of growth, in contradistinction to the general rule in idiopathic scoliosis however the curvature develops more rapidly during the period of active growth than after growth ceases

All patients who have had paralysis of the trunk should have roentgenograms of the spine in the supine and standing positions every three months. If the curvature is progressing fusion of the spine should be carried out without delay The younger the patient, the greater the necessity for correction and fusion of the curvature, especially if the paralysis is grossly asymmetrical. Efficient external support of a progressive scoliosis is difficult, and if the primary curve is in the dorsal region is virtually impossible. A lumbar curve may be supported in [illegible] or celluloid jacket or a crutch type brace with a fair degree of efficie[illegible]

Before proceeding with the correction and fusion in scoliosis any abduction contracture at the hips must be corrected (p 1391) If the scoliosis is in the dorsal region the vital capacity may be greatly impaired, usually, however this can be improved by the use of empyema blow bottles and balloons, ten to twelve times daily

In the presence of multiple factors of imbalance, as in widespread trunk and spinal weakness inclusion of the lumbosacral joint in the fusion area is often necessary to furnish a stable base for the maintenance of an erect balanced position of the corrected and fused spine von Lackum points out that, on the other hand allowance must be made in some cases for inequality of leg length or buttock atrophy by exclusion of the lower lumbar segments from the fusion area, also if a list of the trunk requires stabilization a small amount of residual curvature should be allowed to remain

In general the extent of the primary curve is calculated according to the method of Risser and Ferguson and the Risser jacket is employed More recently, Blount and Irwin have successfully used the Milwaukee brace for the correction and maintenance of correction particularly for curves above the low lumbar region They have corrected the low lumbar curves and the primary lumbosacral tilts by a modification of the Hoke traction cast. (For further details, see section on Scoliosis Chapter XXIV)

SHOULDER

Operative procedures for paralysis of the muscles about the shoulder are of two types (1) tendon transference and (2) arthrodesis. Both procedures are inadvisable in the presence of extreme paralysis of the muscles of the forearm and hand, and when paralysis of the muscles of the shoulder girdle is so extensive as to cause instability of the scapula and inability to elevate the shoulder girdle. In many cases of moderately extensive paralysis or weakness of the shoulder and shoulder girdle there will be some doubt as to the feasibility of tendon transference if the operation is unsuccessful however the shoulder may always be fused at a later date. These patients usually lack full freedom of motion in the scapula compared with those who have had an arthrodesis primarily

Deformities are rarely sufficiently severe to cause extreme disability from contracture of unopposed muscles alone. Usually a slight deformity may be corrected at the time either of the above two procedures is carried out.

Tendon Transference of Trapezius Muscle for Paralysis of Deltoid Muscle

Mayer s procedure is based upon Lange s silk tendon prolongation of the trapezius, wherein numerous silk strands were threaded through the trapezius, passed distally and attached to the humerus at the insertion of the deltoid tendon. Mayer employs an artificial tendon of fascia lata instead of silk. *In addition to the trapezius the serratus anterior the pectoralis major rhomboides and levator scapulae muscles must be active The procedure is contraindicated in the presence of a subluxation of the shoulder joint* Mayer s procedure affords best results when some deltoid power remains.

Technic (Mayer) —A curved incision is made along the clavicle the acromion and the spine of the scapula exposing the insertion of the trapezius muscle (Fig 987) An additional incision is made vertically downward over the outer aspect of the arm from the acromion to the deltoid tuberosity The

trapezius is severed from its insertion and dissected upward a distance of three or four inches, until the nerves and blood vessels are seen entering its deep surface. Care must be exercised to find the cleavage plane between the trapezius and the supraspinatus posteriorly, and between the trapezius and the sternomastoid anteriorly. The deltoid is also exposed subcutaneously and is split longitudinally at its insertion for a distance of one and one-half inches.

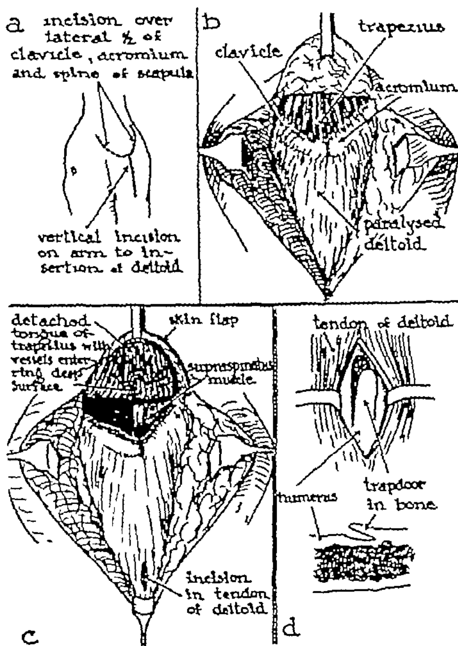


Fig. 987.—Mayer transplantation of trapezius to replace paralyzed deltoid. *A*, Line of skin incision. *B* Exposure of operative field after dissection of skin flap. *C* Trapezius, freed from its insertion to scapula, turned proximally exposing fibers of supraspinatus. Deltoid muscle incised longitudinally. *D* Trap door created in humerus through slit in deltoid muscle. (From Mayer L. Dean Lewis' *Practice of Surgery* Hagerstown, Md., 1947 W F Prior Co. Inc.)

A trap door of bone is then elevated from the cortex of the humerus. Through a nine-inch incision on the lateral aspect of the thigh, a strip of fascia lata is removed, its base being three and one-half to four inches in width and one extremity being tapered to an acute angle (Fig 988). The strip of fascia should

be long enough to reach from the uppermost part of the exposed muscle down to the insertion of the deltoid while the arm is in the elevated position By means of interrupted sutures, the fascia is then fastened to the deep surface of the trapezius as far proximal as possible (Fig 989) The fascia should be held flat and its rough surface should face the muscle Additional sutures hold the distal part of the muscle to the fascia A second strip of fascia, smaller than the first, somewhat triangular in shape and measuring approximately three inches on each side is removed and fastened to the superficial surface of the trapezius thus ensheathing the muscle between the two layers of fascia The arm is now elevated to 135 degrees and the large fascial strip is fastened to the anterior and posterior borders of the deltoid by interrupted sutures. The tapered end of the fascia is next threaded with a long fixation suture and securely anchored in the bony channel prepared by the elevation of the trap door at the deltoid insertion The strip must be fastened to the bone with sufficient tension to hold the muscle and fascia taut when the arm is elevated.



Fig. 988.—Same as Fig. 987 Removal of fascial graft. *A* Line of skin incision. *B* Dotted line shows shape of two grafts. *C* Nonfraction surface of large graft is placed in contact with deep surface of trapezius tendon. Smaller graft will cover its superficial surface. (From Mayer L. Dean Lewis' Practice of Surgery Hagerstown, Md., 1947 W F Prior Co., Inc.)

After Treatment.—The arm is immobilized in a plaster spica in 135 degrees abduction and with the shoulder flexed to a position of 20 degrees anterior to the frontal plane. After four weeks, exercises are begun Immobilization should be continued however for a minimum of four more months and during this time the arm should not be allowed to fall to the side.

Haas obtained a satisfactory result in more than half of a series of thirty cases of paralysis of the deltoid muscle treated by a trapezius fascial transplantation. The technic employed was similar to that of the original Mayer technic Haas noted, however that the range of motion gradually decreased as time ensued because of adherence of the fascia to the acromion process over the niche in the bone. To obviate this condition a second operation was carried out wherein the fascial strip was freed and surrounded with a fat graft. Subsequently Haas modified the technic (1935) omitting the niche in the spine of the scapula Instead, the fascia was brought over the acromion process as a flat band and anchored in several places to the deltoid muscle.

Haas recognizes that, if present at the time of operation a subluxation or dislocation of the humerus must be corrected simultaneously by a Nicola

type of tenodesis Otherwise this will prevent strong fixation of the head of the humerus in the glenoid and thereby change the line of pull of the transplant.

In such cases before the fascial transplant is anchored to the humerus, the long head of the biceps is exposed by dissection through the atrophied deltoid and a modification of the original Nicola procedure is performed. The biceps tendon is divided as far distally as possible and if the displacement of the head is to the medial side, the proximal portion is passed through the head of the humerus medial to the greater tuberosity if the displacement is in the lateral or posterior direction the tendon is passed lateral to the greater tuberosity. Thus, the pull of the head of the humerus toward the glenoid will be correct.

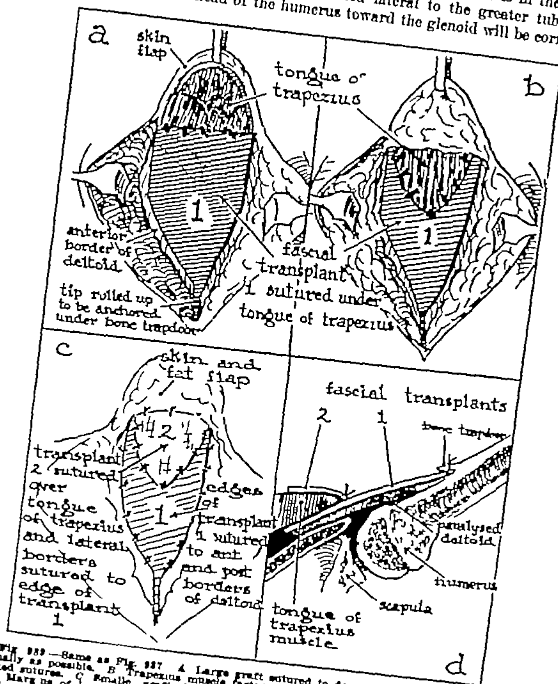


Fig. 939 —Same as Fig. 937 A Large graft sutured to deep surface of trapezius as far proximally as possible. B Trapezius muscle fastened to rough surface of fascial graft by interrupted sutures. C Smaller graft placed over muscle and sutured to both muscle and larger graft. Margins of larger graft sutured to paralyzed deltoid with arm in abducted position pointed end of graft buried in humerus at insertion of deltoid. D Relations of trapezius, two grafts, paralyzed deltoid, and humerus. (From Mayer L. Dean Lewis Practice of Surgery Hagerstown, Md., 1947 W F Prior Co., Inc.)

Following operation, Haas immobilizes the arm anterior to the frontal plane in abduction since failure to do so will have the pernicious effect of forcing the head of the humerus out of the glenoid. This precaution is continued during the later period of protective bracing.

Transference of Biceps and Triceps Muscles for Paralysis of Deltoid Muscle

In complete paralysis of the deltoid muscle Ober employs the biceps and long head of the triceps muscles, provided their power is relatively normal. These structures are formed into a sling over the acromion which more closely approximates the head of the humerus to the glenoid and stabilizes the joint. The better the function in the scapular and pectoral muscles, the more successful the end result.

Technic (Ober).—A saber incision (p. 158) is made over the shoulder, the anterior portion extending three inches distally over the anteromedial aspect of the arm. (More recently, Ober has employed two incisions, one anterior to expose the biceps, and one posteriorly to expose the triceps.) The coracoid process of the scapula is exposed and the short head of the biceps muscle with a small portion of the bony attachment, is removed. The muscle is freed from above downward to the pectoralis major. Occasionally it is necessary to divide the pectoralis tendon in its proximal portion. The tendon is then passed up through the deltoid muscle and out near the tip of the acromion. With a chisel the acromion is cut on the flat so as to raise a flap of bone. The long head of the triceps is next exposed through the posterior leg of the incision, and its origin on the scapula, together with a small segment of bone, is removed. The muscle is then dissected free from the upper fourth of the humerus. Like the biceps tendon, it is passed up through the deltoid, emerging near the posterior aspect of the tip of the acromion. In this region, a bone flap is lifted corresponding in size to the anterior bone flap for the biceps tendon insertion. With the arm in a position of 90 degrees abduction the tendons are sutured to the acromion by means of interrupted silk sutures.

After Treatment.—See above.

Segmental Transplantation of Origin of Deltoid for Partial Paralysis

In some cases the entire deltoid muscle is not paralyzed and the unaffected portion (usually the posterior portion) has good power. Ober in 1935 transplanted the origin of the functioning portion of the deltoid into a more favorable position, with subsequent improvement of the power of abduction. Harmon has recently reported this procedure in detail, citing the case of a patient followed for four years. The posterior portion of the deltoid had good residual power though the anterior and middle portions were completely paralyzed; there was also a pathologic anterior dislocation on attempted abduction of the shoulder. Function of the shoulder was greatly improved by anterior transplantation of the functioning portion of the deltoid. The recurrent dislocation was also corrected by the operation.

Technic (Harmon).—An eight inch curved incision is made extending from the middle third of the clavicle around the shoulder just below the level of the acromion, to the middle of the spine of the scapula. Flaps of skin and subcutaneous tissue are raised superiorly and inferiorly. The active posterior segment of the deltoid is detached subperiosteally from its origin and freed distally from the deep structures for about half its length with care to avoid injury to the axillary nerve and its branches. The outer third of the clavicle

is exposed subperiosteally and the muscle flap is brought forward and anchored to the clavicle by interrupted nonabsorbable sutures to the adjacent soft tissue structures The arm is placed in 75 degrees of abduction in a frontal plane

After Treatment—A shoulder spica is applied maintaining the arm in the desired position After three weeks the upper half of the arm portion of the cast is removed for massage and active motion The entire cast is removed in six weeks and an abduction humerus splint is fitted to be worn for at least four months Supervised active exercises and physical therapy are continued during this time

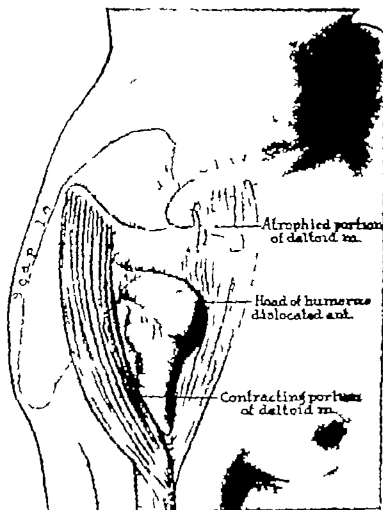


Fig. 990—Harmon segmental transplantation of origin of deltoid, for partial paralysis. Functioning posterior deltoid relation of muscle to humeral head. (From *Harmon, P H.* Surg., Gynec. & Obst. 84 117 1947)

Arthrodesis

If paralysis about the shoulder joint is extensive, stabilization by arthrodesis is the procedure of choice. This is particularly true in the presence of paralytic dislocation of the shoulder wherein the muscles of the forearm and hand are not involved. Lack of motion in this joint is compensated for by the action of muscles which control the movements of the scapula.

The Research Committee of the American Orthopedic Association has reported a survey of the end results following one hundred and one shoulder

fusions for infantile paralysis Though these findings apply especially to paralytic cases, they are also applicable to cases wherein arthrodesis is indicated for other reasons, particularly in regard to the selection of the optimum position for arthrodesis

Their findings are summarized below

1 The humerus should be fused in relation to the scapula rather than to the chest

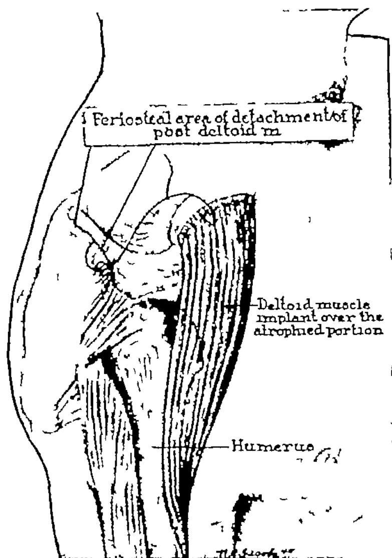


Fig. 331.—Same as Fig 330. Transplanted deltoid overlying atrophied portion. On contracture, transplant retains humeral head in glenoid, and exerts more direct force in abduction than in its former location. (From Harmon, P H. Surg., Gynec. & Obst. 84: 117 1947)

2. With a medium or good trapezius and serratus anterior function 135 to 125 degrees of abduction 165 to 155 degrees of flexion, and 165 to 155 degrees of internal rotation are best. Over 135 degrees of abduction in the shoulder joint produces some winging of the scapula, though abduction up to 125 degrees is satisfactory in the male patient under twelve years of age

3 Good function of the fused shoulder depends upon the presence of good power in the upper trapezius and the upper two thirds of the serratus anterior muscles. The upper portion of the trapezius muscle acts as an elevator of the acromion the shoulder girdle pivoting on the sternoclavicular joint, even in the absence of function in the serratus anterior muscle. If the serratus

is exposed subperiosteally and the muscle flap is brought forward and anchored to the clavicle by interrupted nonabsorbable sutures to the adjacent soft tissue structures. The arm is placed in 75 degrees of abduction in a frontal plane

After Treatment.—A shoulder spica is applied, maintaining the arm in the desired position After three weeks the upper half of the arm portion of the cast is removed for massage and active motion. The entire cast is removed in six weeks, and an abduction humerus splint is fitted to be worn for at least four months Supervised active exercises and physical therapy are continued during this time.

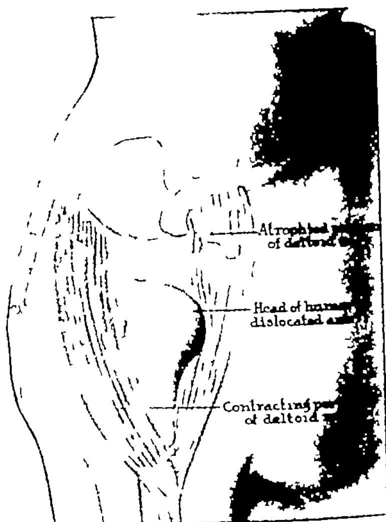


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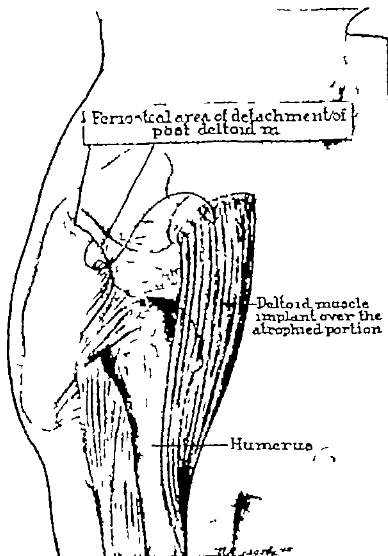


Fig. 931.—Same as Fig. 930 Transplanted deltoid overlying atrophied portion. On contracture, transplant retains humeral head in glenoid, and exerts more direct force in abduction than in its former location. (From Harmon, P H. Surg., Gynec. & Obst. 84: 117 1947)

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is exposed subperiosteally and the muscle flap is brought forward and anchored to the clavicle by interrupted nonabsorbable sutures to the adjacent soft tissue structures. The arm is placed in 75 degrees of abduction in a frontal plane.

After Treatment.—A shoulder spica is applied maintaining the arm in the desired position. After three weeks the upper half of the arm portion of the cast is removed for massage and active motion. The entire cast is removed in six weeks, and an abduction humerus splint is fitted to be worn for at least four months. Supervised active exercises and physical therapy are continued during this time.

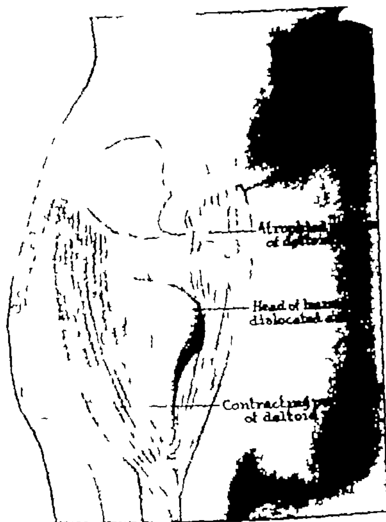


Fig. 990.—Harmon segmental transplantation of origin of deltoid for partial paralysis. Functioning posterior deltoid relation of muscle to humeral head. (From Harmon, P. H.: Surg., Gynec. & Obst. 84: 117, 1947.)

Arthrodesis

If paralysis about the shoulder joint is extensive stabilization by arthrodesis is the procedure of choice. This is particularly true in the presence of paralytic dislocation of the shoulder wherein the muscles of the forearm and hand are not involved. Lack of motion in this joint is compensated for by the action of muscles which control the movements of the scapula.

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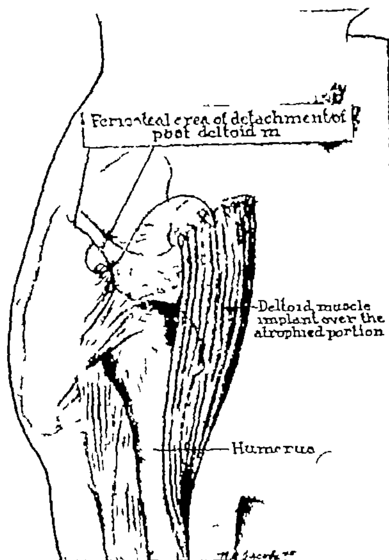


Fig. 811.—Same as Fig. 810 Transplanted deltoid overlying atrophied portion. On contracture, transplant retains *humeral head in glenoid*, and exerts more direct force in abduction than in its former location. (From Harmon, P H. Surg Gynec. & Obst. 84: 117 1947)

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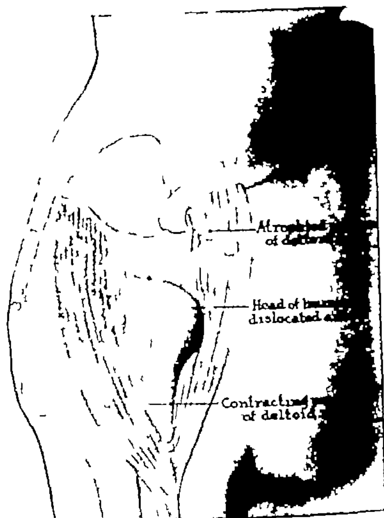


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Arthrodesis

If paralysis about the shoulder joint is extensive stabilization by arthrodesis is the procedure of choice This is particularly true in the presence of paralytic dislocation of the shoulder wherein the muscles of the forearm and hand are not involved Lack of motion in this joint is compensated for by the action of muscles which control the movements of the scapula.

The Research Committee of the American Orthopedic Association has reported a survey of the end results following one hundred and one shoulder

fusions for infantile paralysis Though these findings apply especially to paralytic cases they are also applicable to cases wherein arthrodesis is indicated for other reasons, particularly in regard to the selection of the optimum position for arthrodesis

Their findings are summarized below

1 The humerus should be fused in relation to the scapula rather than to the chest

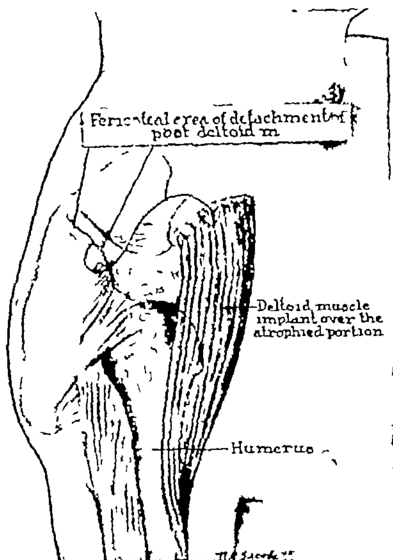


Fig. 991.—Same as Fig. 990. Transplanted deltoid overlying atrophied portion. On contracture, transplant retains humeral head in glenoid, and exerts more direct force in abduction than in its former location. (From Harmon, P. H. Surg. Gynec. & Obst. 84: 117 1947.)

2 With a medium or good trapezius and serratus anterior function 135 to 125 degrees of abduction 165 to 155 degrees of flexion and 165 to 155 degrees of internal rotation are best Over 135 degrees of abduction in the shoulder joint produces some winging of the scapula, though abduction up to 125 degrees is satisfactory in the male patient under twelve years of age.

3 Good function of the fused shoulder depends upon the presence of good power in the upper trapezius and the upper two-thirds of the serratus anterior muscles The upper portion of the trapezius muscle acts as an elevator of the acromion, the shoulder girdle pivoting on the sternoclavicular joint even in the absence of function in the serratus anterior muscle. If the serratus

is exposed subperiosteally and the muscle flap is brought forward and anchored to the clavicle by interrupted nonabsorbable sutures to the adjacent soft tissue structures. The arm is placed in 75 degrees of abduction in a frontal plane.

After Treatment.—A shoulder spica is applied maintaining the arm in the desired position. After three weeks, the upper half of the arm portion of the cast is removed for massage and active motion. The entire cast is removed in six weeks and an abduction humerus splint is fitted, to be worn for at least four months. Supervised active exercises and physical therapy are continued during this time.

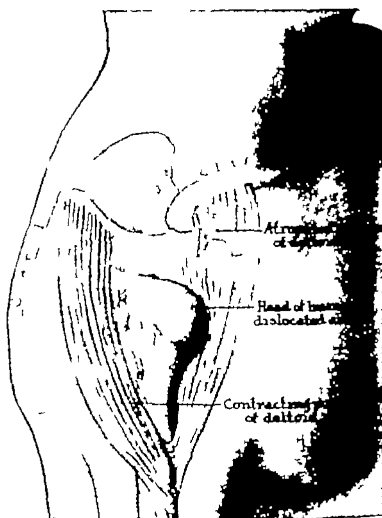


Fig. [illegible].—Harmon segmental transplantation of origin of deltoid, for partial paralysis. Functioning posterior deltoid; relation of muscle to humeral head. (From Harmon, P. H.: Surg., Gynec. & Obst. 84: 117, 1947.)

Arthrodesis

If paralysis about the shoulder joint is extensive, stabilization by arthrodesis is the procedure of choice. This is particularly true in the presence of paralytic dislocation of the shoulder wherein the muscles of the forearm and hand are not involved. Lack of motion in this joint is compensated for by the action of muscles which control the movements of the scapula.

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From a clinical standpoint abduction of the arm of 110 to 90 degrees from the body, forward flexion on the scapula of 165 to 155 degrees and tilting upward of the flexed forearm 25 to 30 degrees above the horizontal will give the best position of fusion in the majority of cases Internal rotation will thus be approximately 155 degrees when the arm is brought down to the side

9 Special problems

Scoliosis.—There is no definite evidence that fusion of the shoulder has a deleterious effect upon scoliosis A scoliosis will limit the range of scapular motion In the presence of a severe curve with the convexity toward the shoulder to be fused too much flexion must be avoided otherwise excess winging will result and will in turn accentuate the deformity

Age.—A wider range of motion is restored if fusion is carried out before the patient reaches the age of twelve There is little danger of epiphyseal damage.

Bilateral Paralysis—If fusion of both shoulders is necessary a position should be selected which will permit the patient to bring the hands together If muscle power differs in the two shoulders the weaker should be placed in a greater degree of internal rotation. If the power in the two shoulders is approximately equal the left shoulder should be placed in a greater degree of internal rotation in a right handed individual and vice versa

The Flail Shoulder—Fusion of the flail shoulder offers the following advantages greater ease in turning in bed and putting on a coat better use of the hand to steady paper while writing and an added feeling of security or stability in the shoulder In the weak or flail shoulder only slight abduction is desirable Flexion power of the elbow may be improved following stabilization.

10 When the roentgenogram reveals evidence of beginning fusion of the shoulder no further change in abduction will develop

The operative technic of arthrodesis is described in Chapter XV

ELBOW

Since gravity will extend the elbow, surgery is practically limited to measures for restoration of active flexion in paralysis or weakness of the brachialis anticus, biceps, and brachioradialis muscles. Other measures designed to maintain the elbow in flexion consist of plastic operations on the skin and tendon transference of the triceps to the anterior surface of the elbow These, however are unsatisfactory Any procedure for restoration of function in this joint is worthless in the presence of inactive flexor muscles of the wrist and fingers. Arthrodesis or fusion of the elbow is practically never employed.

Steindler has devised a technic which has entirely supplanted other methods. This operation is designed to restore active flexion by transference of the common origin of the flexor muscles of the forearm from the internal epicondyle to a higher point on the humerus. The results depend entirely upon the strength of the flexor muscles, and thus the effectiveness of the operation diminishes proportionately with the decrease in power of these structures.

For stabilizing the elbow Putti recommended a technic which blocks extension. The principle is similar to that emboded in Campbell s bone block operation for drop foot. This procedure may be employed alone or combined with Steindler s operation to prevent overstretching of the transferred muscles from gravity

anterior is inactive, the trapezius can abduct the shoulder to only 135 degrees. If the shoulder is fused in a position of more than 135 degrees abduction despite the lack of serratus anterior function the weight of the arm may rotate and depress the outer portion of the scapula leading to overstretching and weakening of the trapezius. Thus, if function in the serratus anterior has been lost, the shoulder should be fused in no more than 150 degrees of abduction in relation to the vertebral border of the scapula

4 If the trapezius retains a moderate amount of power and all the other muscles about the shoulder are paralyzed some improvement in appearance and function may be restored by fusion The flail shoulder is usually carried higher than normal following fusion its appearance is improved in that normal alignment is restored.

5 In aligning the shoulder joint postoperatively an adduction contracture of the scapulohumeral joint must be kept in mind restoration of the correct degree of abduction is impossible without correction of the contracture itself.



Fig. 882.—Before and after arthrodesis of shoulder for flail joint.

6 True abduction in the shoulder is measured by the angle between the vertebral border of the scapula and humerus Because of the tendency of the angle to become changed in the postoperative plaster cast, internal fixation is advised.

7 Fusion of the shoulder in too much flexion will also lead to winging of the scapula and stretching of the serratus anterior If flexion is not over 165 degrees the weight of the arm will cause the scapula to lie flat against the thorax, even though the serratus anterior is paralyzed. On the other hand, fusion without flexion results in poor function. In the majority of patients, the position of 135 to 130 degrees of abduction and 145 to 140 degrees of flexion with the body planes will afford the proper degree of flexion.

8 Too little internal rotation is worse than too great internal rotation. The hand may be placed on top of the head with 145 to 140 degrees of abduction provided internal rotation is no more than 165 degrees. In the presence of a weak elbow and hand, however the shoulder may be fused in greater internal rotation if the opposite arm is uninvolved. Even so internal rotation should not exceed 135 degrees.

if the hand is to be placed on top of the head when the patient is erect, sufficient power must be present in the triceps to extend the elbow against gravity Thrusting and pushing motions with the forearm and hand also require triceps power

Ober and Barr devised a method of transposing the brachioradialis muscle in weakness of the triceps Should the power of the brachioradialis be inadequate added strength is obtained by transplantation of the extensor carpi radialis longus muscle The brachioradialis muscle is transposed from the lateral to the posterior lateral aspect of the elbow and forearm behind the lateral condyle of the humerus.

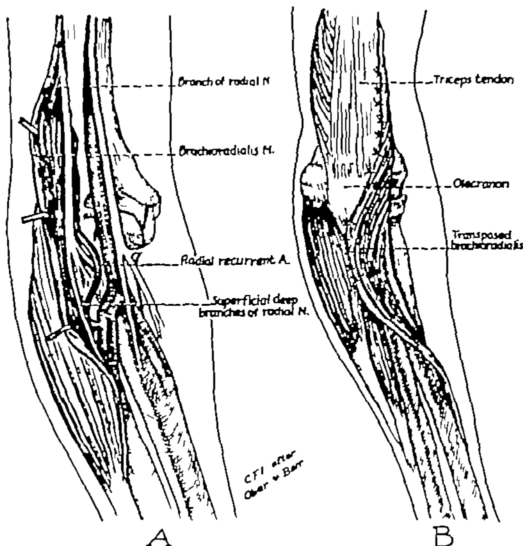


Fig. 994 —Transference of brachioradialis muscle for paralysis of triceps (Ober and Barr) A Brachioradialis muscle retracted, showing relation to radial nerve. Nerve supply enters muscle proximally B, Position of muscle after transference. (Redrawn from Ober F R., and Barr J S. Surg. Gynec. Obst. 67 105 1938.)

Technic (Ober and Barr) —The skin incision begins on the posterior lateral aspect of the humerus, three or four inches above the lateral epicondyle, extends distally just posterior to the epicondyle and ends four inches below the head of the radius on the lateral aspect of the forearm. *In making the* skin incision care should be taken to avoid injury of the dorsal cutaneous nerve of the forearm The anterior margin of the *brachioradialis* muscle is defined and dissection carried distally and proximally until the nerve and blood supply are well isolated during dissection the recurrent radial artery and the

Transference of Flexor Muscles of Forearm at Elbow

Technic (Steindler).—A curved longitudinal incision is made on the inner side of the elbow, beginning three inches above the internal epicondyle and extending distally behind the internal condyle, thence forward on the volar surface of the forearm, following the course of the pronator radii teres muscle. The ulnar nerve is located behind the internal epicondyle and retracted posteriorly. The common origin of the pronator radii teres, the flexor carpi radialis, the palmaris longus, and flexor carpi ulnaris muscles is detached en masse at the internal epicondyle close to the periosteum. Distally these muscles are freed for one and one-half inches, then, with the elbow in flexion, they are transferred proximally to a point two inches above the internal epicondyle into the intermuscular septum between the triceps and brachialis anticus muscles or to the periosteum of the humerus and fixed to the soft structures by strong sutures.

Campbell has slightly modified the above technic as follows: after defining the common origin of the flexor muscles, practically the entire internal epicondyle with the attachments of these muscles is removed with an osteotome. This muscle bone flap is then transferred to the humerus above, the cortex of the humerus having first been scarified at the point of contact. Fixation is secured by No. 1 chromic catgut sutures through the adjacent intermuscular septum or through holes drilled in the humerus.

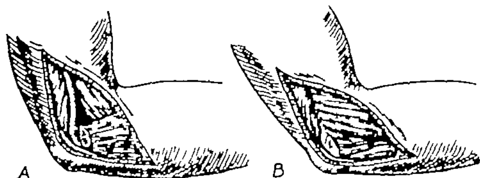


Fig. 992.—Steindler transference of flexor muscles of forearm for paralysis of flexor muscles of elbow joint. *A*, Common origin of flexor muscles detached from condyle of humerus. *B*, Muscles freed for 1½ inches, transferred proximally to a point two inches above internal epicondyle, and sutured in interval between triceps and brachialis anticus muscles.

After Treatment.—By means of a plaster cast the elbow is immobilized in acute flexion, with the forearm in a position midway between pronation and supination. After two weeks the cast is replaced by a splint which maintains the arm in this position for at least six weeks, and physical therapy and active motion are instituted to increase the strength of the transferred muscles.

The best end results are obtained when the flexors of the elbow are only partially paralyzed and the flexors of the wrist possess normal power. The active flexion restored does not compare favorably with the normal power and function of the elbow but increases the usefulness of the arm to a practical and worth while degree.

Transference of Brachioradialis Muscle for Paralysis of Triceps Muscle

Weakness or paralysis of the triceps muscle is usually considered of little practical importance since gravity can be made to extend the elbow passively in most of the positions which the arm will assume. A good triceps is necessary, however, to lock the elbow in extension when crutches are used. Also

if the hand is to be placed on top of the head when the patient is erect, sufficient power must be present in the triceps to extend the elbow against gravity Thrusting and pushing motions with the forearm and hand also require triceps power

Ober and Barr devised a method of transposing the brachioradialis muscle in weakness of the triceps. Should the power of the brachioradialis be inadequate, added strength is obtained by transplantation of the extensor carpi radialis longus muscle. The brachioradialis muscle is transposed from the lateral to the posterior lateral aspect of the elbow and forearm behind the lateral condyle of the humerus.

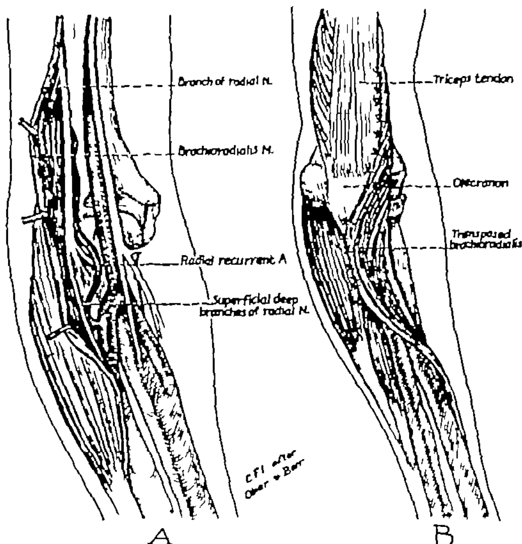


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muscular branches of the radial nerve must be carefully avoided The origin of the muscle is left intact. The freed anterior margin is then rolled laterally and posteriorly and sutured to the fascia and periosteum along the subcutaneous edge of the ulna and olecranon and to the triceps tendon. Detachment of the brachioradialis muscle from its origin should be unnecessary as transposition of the muscle belly to the posterior aspect of the elbow joint suffices to change the function of the muscle from that of a flexor to an extensor of the elbow

After Treatment.—The arm is immobilized in a plaster splint which holds the elbow in full extension and supination. Exercises are begun ten days postoperatively and are continued so long as ability to extend the arm increases.

Posterior Bone Block of the Elbow to Limit Extension

In this operation, a bony abutment is formed in the olecranon fossa whereby contact with the olecranon limits extension beyond 90 degrees but preserves the range of motion from 90 degrees to complete flexion.

In the presence of a weakened biceps muscle, this procedure will prevent overstretching of the muscle and eventual complete loss of power further active contraction from 90 degrees to complete flexion may be possible in a muscle incapable of active contraction from complete extension to complete flexion.

Technic (Putti and Scaglietti)—The posterior surface of the elbow joint is exposed through a curved posterolateral incision (p 162) With an osteotome, a small osseous flap is raised on the posterior articular surface of the humerus, its base proximally and small fragments of bone are removed from the metaphysis of the humerus and packed into the crevice beneath the flap The olecranon process should come in contact with this bony abutment when the forearm is flexed to a right angle.

Putti states that the above technic is more physiologic and is simpler technically and more rapidly executed than his original procedure, described in 1926 In the latter a fissure is created in the posterior surface of the trochlea, extending obliquely upward, and a cortical graft from the tibia approximately one inch long and one-half inch wide is inserted into this fissure. The osseous transplant is so placed as to impede extension of the elbow beyond 90 degrees.

Technic (Boyd)—Through a posterolateral approach (p 162) the distal end of the shaft of the humerus and the elbow joint are exposed. The insertion of the triceps into the olecranon is not disturbed To provide a raw bony surface for the reception of the graft, the cortex of the shaft of the humerus just proximal to the olecranon fossa is denuded of its outer cortical layer of bone. A three inch tibial graft is then placed on this bed, with its cancellous surface in contact with the raw humeral bed the graft should extend distally to form a block to extension of the elbow beyond the desired position of 90 degrees The block is accomplished by the impingement of the tip of the olecranon against the distal end of the graft. The desired position of the graft having been determined the graft is attached to the humerus by one or two screws (Fig 996)

If a Steindler flexorplasty of the elbow is performed (p 1420) at the same time the two procedures may be carried out through the same approach by extending the flexorplasty incision proximally The ulnar nerve must be isolated and protected throughout the operation.

After Treatment.—The elbow is immobilized at a right angle in a plaster cast extending from the axilla to the palm Two months postoperatively the cast is removed and physical therapy initiated

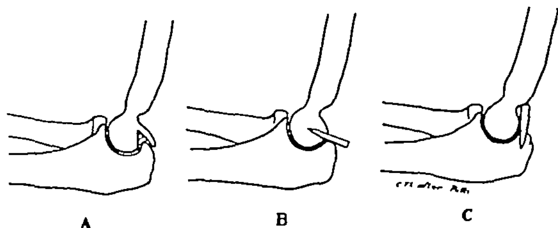


Fig. 995.—Posterior bone block to limit extension of elbow (Technic of Putti and Scaglietti.) *A*, Preferred technic Small osseous flap raised from posterior articular surface of humerus, defect being filled with chips from adjacent metaphysis. *B* and *C* Bone block with small tibial pegs.

Fig. 996.—Posterior bone block of elbow (modification of Putti technic) formed by cortical graft from tibia applied to denuded posterior surface of humerus, held in place by one Vitallium screw Transverse wire nail holds attachment of flexor muscles of forearm in position following Steindler operation (Case of Dr H. B. Boyd)

FOREARM, WRIST, AND FINGERS

Operative measures on the forearm and wrist consist of tenotomy and fasciotomy for correction of deformity tendon transference for restoration of function, and arthrodesis for providing stability

Deformity in the forearm is seldom so disabling as to warrant surgery for correction alone. The deformity which most often necessitates operation is fixed pronation, from imbalance between the supinators and pronators. If the pronator teres muscle is not sufficiently active to replace the function of the paralyzed supinators, correction of the deformity alone is indicated, provided active flexion of the elbow is not impaired If the pronator muscles and flexors of the forearm are active, however, function may be materially improved by correction of the pronation contracture and transference of the pronator radii teres and flexor carpi radialis muscles.

Transference of Pronator Radii Teres and Flexor Carpi Radialis Muscles for Paralysis of Supinator Muscles

Technic (Tubby) —An incision six inches in length is made anteriorly in the middle three-fifths of the forearm in line with the radial artery The inner margin of the brachioradialis muscle is defined and separated from the flexor carpi radialis. The radial nerves and vessels should be elevated and retracted to the medial side of the forearm The pronator radii teres, which is a broad muscle with a short, flat tendon, is followed to its insertion the direction of the fibers affording a guide, and the tendon with the adjacent periosteum, is detached from the radius. The flexor carpi radialis is freed, the tendon divided one and one-half inches above the wrist and firmly sutured to the pronator radii teres while both are under tension. The interosseous membrane which is often contracted is severed close to the radius under direct vision with care to conserve the interosseous artery and nerve.

A silk suture is placed in the end of the conjoined tendon and the free ends of the suture are passed through the eye of a fascia needle. The needle is then inserted through the interosseous membrane behind the radius, worked rather vigorously in a vertical and longitudinal direction to remove the soft tissues from the outer surface of the radius, and withdrawn anteriorly The silk suture is then passed through the drill hole from before backward, thence through the portion of the tendon on the posterior surface of the radius, and tied.

After Treatment.—The elbow is placed in 90 degrees' flexion and the forearm in supination and so maintained by a cast for two to three weeks. At the end of this time systematic exercises and physical therapy are instituted to re-educate the transferred muscle Between exercise periods, a splint should be worn to hold the forearm in supination until strong active supination is restored.

This procedure has not proved satisfactory but has served as a basis for more efficient technics. Mayer has modified the Tubby operation as follows

After forming the conjoined tendon by suturing the pronator radii teres to the flexor carpi radialis muscles, these structures are freed as far proximally as their nerve and blood supply will permit. The conjoined tendon is then drawn through a subcutaneous tunnel around the inner border of the arm crossed over the dorsal surface to the radial side, passed through a drill hole in the radius two inches above the wrist, and fixed posteriorly Other suitable procedures are described in the section on Spastic Pronation Contracture of the Forearm p 1499

Unfortunately paralysis or weakness of the muscles of the wrist is often so widely distributed that tendon transference is not feasible If the paralysis is limited to the muscles supplied by a single nerve, particularly the radial

nerve tendon transference may be even more successful in the wrist than in the foot, as weight bearing is not a consideration and the force of gravity is less active. Transference of the flexor muscles to the posterior aspect of the wrist for restoration of dorsiflexion in drop wrist is the most effective of these procedures. *The operation is identical with that described for paralysis from* injury of the radial nerve (p 766)

Complete restoration of function by tendon transference following paralysis of the muscles supplied by the median and ulnar nerves is practically impossible even when only a few of the long flexors are involved and the extensor tendons are normal The distribution of the paralysis is seldom limited to a few of the flexor muscles, as a rule, the paralysis involves not only the flexors, but to some extent the extensors of the wrist as well Thus, in *many* patients even a moderate degree of usefulness cannot be restored In those rare cases wherein the paralysis is limited, the operative technic is similar to that for irreparable loss of continuity of the medial or ulnar nerves (p 778)

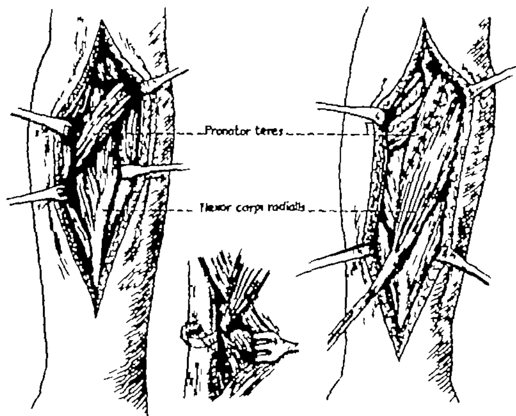


Fig. [illegible]—Transference of pronator radii teres and flexor carpi radialis muscles for paralysis of supinator muscle (Tubby) After pronator and flexor carpi radialis muscles are apposed and sutured, the common tendon is passed through interosseous membrane, around radius, and anchored anteriorly This procedure is less efficient than recent modifications.

Arthrodesis of the wrist joint is indicated in paralysis of the extensor muscles of the forearm and flexion contracture of the wrist, when sufficient power remains in the flexors of the fingers and wrist for partial function, yet not for tendon transference. In these circumstances arthrodesis effects a satisfactory correction of the flexion contracture and places the wrist in the most suitable position for active function of the *flexor muscles*. This procedure is described in Chapter XV

In *order to obtain* stability of the wrist, yet retain some degree of motion Steindler advocates arthrodesis of only the radiocarpal articulation with oblitera

tion of the joint between the radius, scaphoid, and semilunar bones. Fus these joints limits principally volar flexion and adduction whereas dorsif and abduction, movements in which the intracarpal articulation is concerne preserved to a degree.

Osteoclasis for Supination Deformities of the Forearm

In 1940 Blount called attention to the supination deformity of the arm which occasionally follows infantile paralysis and, more rarely, f brachial birth paralysis. This deformity results from vicious muscl balance usually poor pronators and finger flexors in the presence of a str biceps and forearm and wrist extensors. Usually there is an associated b of the distal end of the radius and shortening and dorsal bowing of the An ulnar deviation of the hand may accompany these changes. For the c tion of this deformity Blount has utilized a manual osteoclasis of the n third of both bones of the forearm. This procedure is specifically indi for those cases wherein muscle power is insufficient for tendon transfe Twelve years is the upper age limit. Overcorrection of the deformity portant since some degree of recurrence will take place both upon remo the cast and with further growth. In several of Blount's cases refra and correction were necessary because of this loss of initial correction

Technic (Blount) —The affected arm is abducted and externally ro to bring the wrist near the shoulder The forearm is placed in midpronat nearly as possible with the dorsum of the hand toward the table in this po there are no important soft structures between the bones and a padded wedge. The surgeon stands on a bench, grasps the forearm on each side c wedge and with a quick straight arm thrust, fractures the bones. The is then reversed to complete the fracture and the forearm is bent back and forward several times to insure completion of the fracture The for is then pronated between 45 and 90 degrees and is fixed in this position plaster cast extending from the axilla to the metacarpophalangeal joints the elbow at 90 degrees. Immobilization should be continued from six to weeks. If the deformity cannot be fully corrected without undue bony placement at the time of osteoclasis the forearm may be remanipulated ten to fourteen days to complete the correction.

INEQUALITY IN LENGTH OF THE LOWER EXTREMITI

Regardless of expert care, a shortened extremity may be unpreventabl lowing many orthopedic affections. The difference in length of the l extremities, even though otherwise normal, produces a limp and p obliquity with a compensatory scoliosis of the spine In the majority of c the shortening of an extremity may be satisfactorily compensated fo means of an elevation on the shoe. An elevation, however is rather sightly and sufficiently cumbersome to be fatiguing particularly in presence of paralysis. Three types of operations have been devised for eq izing the length of the extremities (1) lengthening of the short leg diminishing the length of the normal extremity by resection, and (3) in dren, epiphyseal arrest.

Harris and McDonald employ lumbar sympathectomy to increase the b supply to a poliomyelitic extremity with shortening Since 1928 they have formed this procedure in 300 cases. In children, a lasting hyperemia is duced, and a definite increase in the rate of growth on the operated side o

follows. According to these authors, there is a basic rate of growth which in normal legs, is stimulated by normal muscle activity and a normal blood supply. In a severely paralyzed extremity sympathectomy improves the blood supply but otherwise is usually ineffective since other factors, such as diminished function and weight bearing, affect growth of the leg. Although lumbar sympathectomy may be followed by a prolonged hyperemia and relief of the chilblain and pain associated with the poor circulation it does not produce a consistent or material increase in growth of the affected extremity. For this reason the procedure has not been widely employed.

At the present time Harris and McDonald excise the lumbar trunks and ganglia below the first lumbar ganglion. The results have been so encouraging that they employ the method in all patients who exhibit a beginning difference in leg length following poliomyelitis. Following poliomyelitis involving the lower extremity, the leg length is checked at frequent intervals; as soon as a difference in length appears, a lumbar sympathectomy is performed on the affected side. In their experience when the full vasodilator effect has been secured and maintained by lumbar sympathectomy progressive shortening will cease, and not infrequently the shortening will decrease. In their cases, the greatest gain in leg length has been one and one half inches. (We have had no personal experience with this method.)

LEG LENGTHENING

Leg lengthening is an operation of such magnitude that it must never be taken lightly. A study of the reports of Compere, B. H. Moore, Abbott and Saunders, Bost, Bosworth, Brockway and Fowler, Phalen, Chatterton, Wilson and Thompson reveal numerous complications which may arise in conjunction with these procedures. As Compere has said, Interest in the successful cases has sometimes detracted from the lessons that might be learned from the failures.

The complications of leg lengthening have been listed by Abbott and Saunders as follows:

(1) Deformities of the foot: (a) valgus, (b) equinus, (c) equinovalgus, and (d) calcaneovalgus. These usually arise from failure of the soft parts to lengthen proportionately with the bones, the soft parts involved being the deep fascia, intermuscular septa, interosseous membrane, periosteum, and the tendinous content of the muscles and the tendons.

(2) Deformities of the knee: (a) genu valgum, (b) flexion contracture, and (c) relaxation of the knee.

(3) Anterior and medial bowing of the fragments of the tibia with malunion or nonunion.

(4) Limitation of motion at the ankle. This is probably a result of a traumatic arthritis from the tremendous pressure on the articular surfaces of the joint. A malalignment of the ankle may also be present, aggravating the condition. B. H. Moore has called attention to the fact that the change usually produced is a flattening of the dome of the astragalus under the tibia, which may limit ankle motion in dorsiflexion and plantarflexion. Severe decalcification of the tarsal bones out of proportion to the atrophy elsewhere may be associated.

(5) Weakening of the muscles of the leg.

(6) Nerve complications (a) Paralysis or weakening of the muscles and (b) disturbance of sensation. These are the result of overstretching during the lengthening procedure and usually disappear spontaneously

(7) Disturbance of circulation (chronic swelling of the leg) This is usually not serious nor permanent. Campbell however has observed a case of complete gangrene of the leg distal to the area of lengthening

(8) Infection (a) Infection of the operative wound and (b) infection of pin wounds. Infection of the wound may follow pressure necrosis of the skin and soft tissues with attendant osteomyelitis, incident to lack of complete control of the fragments. Pin wound infection may arise from the trauma of insertion, pressure necrosis of the soft tissues and bone, too frequent changes of dressings, and from migration of the pins from side to side.

(9) Aseptic necrosis of bone (Compere) from too extensive stripping of the periosteum. In the presence of an infection this aseptic necrosis may become septic, with all the complications and sequelae of an osteomyelitis.

In the light of these numerous possibilities, Compere states that he regards shortening of the normal extremity by epiphyseal arrest or resection as preferable to lengthening of the short leg when (1) the discrepancy is less than 3 cm., (2) the patient is less than fifteen or sixteen years of age, (3) the muscles of the hip or knee are weak or paralyzed (4) shortening is so marked that maximum lengthening will not equalize the extremities sufficiently to enable the patient to discard lengthening appliances, (5) there is a history or clinical and roentgenographic evidence of previous osteomyelitis in the short leg or other disease in the bone to be lengthened, i.e., fibrocystic disease or (6) when the abnormality is congenital, as in the absence of part of the bone to be lengthened or other severe deformities in which an artificial limb would permit better use of the extremity

In our experience which has been limited to only a few cases, leg lengthening is an extremely formidable procedure, involving a long period of disability and much suffering Because of this fact as well as the possibility of dangerous complications, the operation is, in our opinion rarely justified. Only young adults who have attained their full growth and who have a shortening of two inches or more are suitable subjects further function at the hip and knee should be unimpaired, and the osseous structure of the tibia should be normal A shortened extremity frequently is a poor site for extensive surgery The bones and soft tissues may be atrophic from disuse, the musculature may be weak, and the blood supply relatively poor These alone predispose numerous complications. In every case, the patient should be advised as to the extremely long convalescence required and the possibility of securing an equally good result by shortening of the opposite extremity with the prospect of returning to normal activity within a much shorter period of time.

Many patients with a severe limp attribute this disability to shortening alone, whereas paralysis, particularly of the gluteal muscles, may be the principal contributing factor Equalization of leg length will only partially correct the abnormal gait this fact should be explained to the patient prior to operation The presence of fixed pelvic obliquity should be ruled out before operation since this deformity may impair the clinical result following leg lengthening

Putti, Abbott, Bost, Crego B H. Moore, Bosworth, Brockway White, Compere and Durham have been instrumental in developing the technic of leg

lengthening to the point of practicability Abbott states that in the operation on the lower extremity, three principles must be observed

1 Traction and counter traction must be exerted directly upon the bone to be lengthened

2. This traction must of necessity be slow and continuous.

3 Pressure necrosis of the skin and subsequent infection of the bone must be prevented by measures to maintain the fragments in accurate contact and alignment during the lengthening process This is obviously much easier in lengthening of the tibia and fibula than in the femur Under any circumstances, however, constant observation and daily adjustment of apparatus are required

Lengthening of the Tibia and Fibula

In the early period of development of leg lengthening procedures, many of the complications were the direct result of the use of imperfect apparatus. Abbott and Crego devised a simple but efficient splint for lengthening the

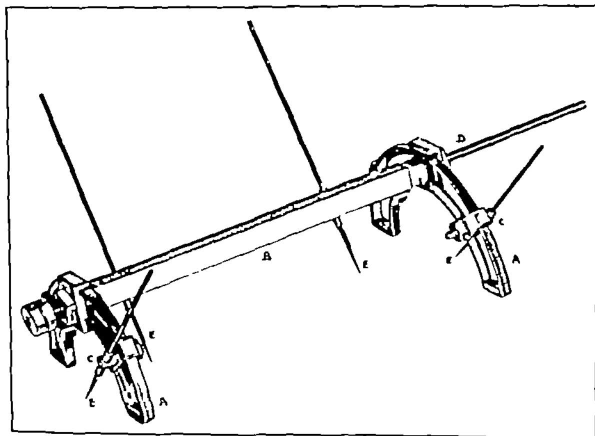


Fig. [illegible].—Apparatus of Dr Francis West for leg lengthening. Oblique pin apparatus assembled. *A* Halfhoops with curvilinear notches. *B*, Rectangular telescoping segments. *C* Adjustable pin clamps. *D* Threaded bar with nut and recoil spring. *E* Four stainless steel pins. (Courtesy of Dr Francis West.)

tibia and fibula, consisting of (1) Four stainless steel drill pins (2) an adjustable pin guide, and (3) a combined traction and supporting splint. Dr Francis West an associate of Dr Abbott, improved the equipment. This apparatus is described as follows

In assembling the apparatus, the hollow segments are telescoped over each other The threaded traction bar with the recoil spring is passed down

their centers and the ends are fixed to the two half hoops by nuts and screws. The four adjustable clamps are now attached to the two half hoops, two are placed so that their metal cylinders lie above and below the metal hoops the other two with their cylinders lie on the medial surfaces of the hoops.

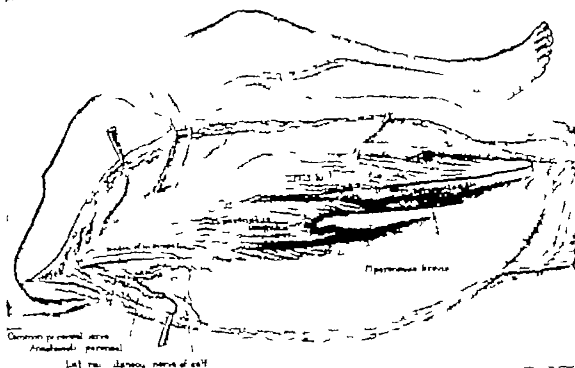


Fig. [illegible].—Lengthening of tibia and fibula by technic of Abbott and Saunders. First stage. Origin of extensor-evertor muscles and relation of common peroneal nerve to biceps tendon. Insert shows skin incision. (From Abbott, L. C., and Saunders, J. B. deC. M. Ann Surg. 110: 961 1939.)

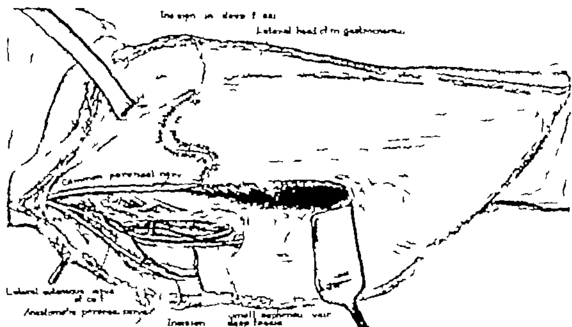


Fig. 1040.—Same as Fig. [illegible]. First stage. Method of dividing deep fascia and line of detachment of origin of muscles. (From Abbott, L. C., and Saunders, J. B. deC. M. Ann. Surg. 110: 961 1939.)

During the application the apparatus is held over the anterior surface of the leg by an assistant The four clamps with rotating cylinders are moved along the curvilinear notches in the half hoops until the cylinders point in an oblique direction towards the middle of the lateral and medial surfaces of the upper and lower ends of the tibia The pins are passed through the

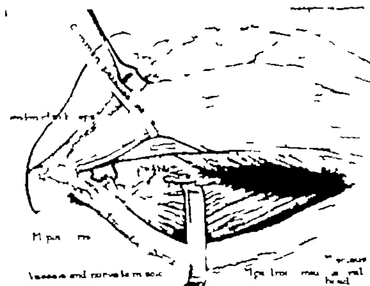


Fig. 1001—Same as Fig. 999 First stage Exposure of vessels and nerves to soleus by dissection posterior to fibula. (From Abbott, L. C., and Saunders J B. deC. M.: Ann. Surg. 110: 961 1939)

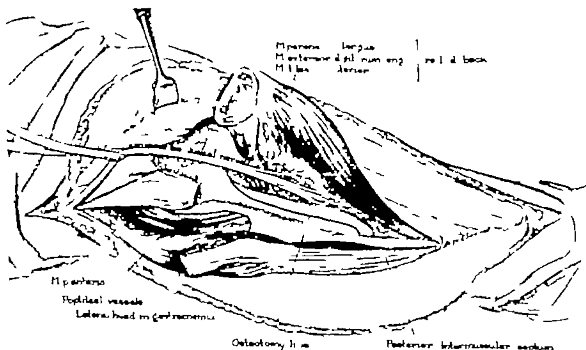


Fig 1002.—Same as Fig. 999 First stage Origin of extensor muscles released together with fragment of bone, muscles retracted, fibula osteotomized. (From Abbott, L. C., and Saunders, J B. deC M Ann. Surg. 110 961 1939)

cylinders and turned through the corresponding cortices of the shaft of this bone All four pins also pass through the posterior cortex of the tibia. With the pins engaged, the clamps holding the cylinders are fixed to the curvilinear notches in the half hoops.

Since, in this country Abbott has been largely responsible for the development of this operation and perhaps is more familiar with its use than any other surgeon, we shall draw from his experience He and Saunders, recognizing that resistance of the fibrous structures of the leg constitute an important basis for malalignment of the tibia and fibula postoperatively have made a careful study of the anatomy of the leg with particular reference to these structures. They found that the muscles of the leg must be freed sufficiently from their origin to permit such osteotomies as would allow bodily migration of these muscles with the descending fragments of the bones. The dissections also revealed that the tension placed upon the intact gastrocnemius muscle causes the malalignment of the tibial fragments in the anteroposterior plane, while the soleus plays no part after its origin is released To release the tension on the gastrocnemius its tendon is divided at its junction with the tendon of the soleus and transplanted proximally to the fascial surface of the posterior aspect of the soleus *Osteotomy of the tibia in the vertical plane provides for* maximum retention of the origin of the muscles to the descending fragments with minimum separation of the periosteum and with preservation of the nutrient vessels of the tibia and fibula

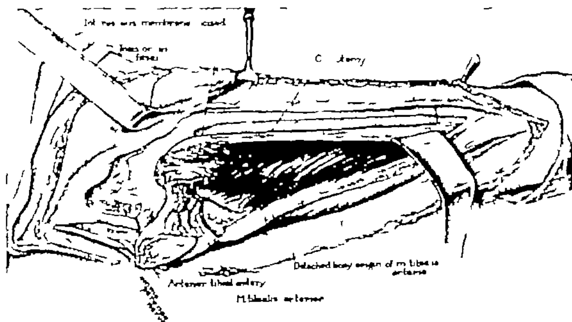


Fig 1602.—Same as Fig. 999 First stage: Exposure of popliteal and anterior tibial arteries. Osteotomy of cortex of tibia extends from arch above to transverse osteotomy of its crest below (From Abbott, L. C., and Saunders, J B. deC. M. Ann. Surg 110: 961, 1939)

Because of its magnitude, this procedure must be performed in two stages. The interval between the two stages should not be more than five or six days, since a longer interval allows the tissues to become too firmly reattached.

As a result of these studies, Abbott and Saunders have described a method of leg lengthening which, though definitely more complicated, is a decided improvement upon former methods. The complications resulting from resistance of the soft structures have been largely eliminated by release of these tissues before the lengthening procedure is begun.

In dealing with infantile paralysis, Abbott prefers not to stabilize the foot before the leg is lengthened thus, if unpreventable deformities of the foot arise during the leg lengthening procedure, they may be corrected by stabilization at a later date.

Technic (Abbott and Saunders).—"First Stage.—The incision commences over the tendon of the biceps femoris on the posterolateral aspect of the knee and is carried downward along the course of this tendon to the neck of the fibula From thence it curves obliquely across the anterolateral aspect of the leg to a point about one inch below the level of the tibial tubercle, there, it follows the crest of the tibia to the junction of the middle and lower thirds of the leg (Fig 999) In general, the incision follows the course of the common peroneal nerve in its upper part and the anterior tibial vessels and nerve in their lower parts. The common peroneal nerve is immediately exposed under cover of the medial border of the biceps tendon It is then traced to the lateral aspect of the neck of the fibula where it is firmly bound down by fascial extensions from the biceps tendon to the deep fascia of the leg In cision of this fascia constitutes an important step because it frees the nerve from its main point of fixation Flexion of the knee will now demonstate a very considerable laxity of the nerve, amounting to as much as one and one half inches. The nerve can then be readily followed to its division into three chief branches, the upper being the recurrent articular, the intermediate, the deep peroneal and the lower, the superficial peroneal These branches with their subdivisions are now traced to their entrance into the muscles In dissecting this nerve it is well to look for the lateral cutaneous and the anastomotic peroneal branches where they are given off the main trunk about two fingerbreadths above the external condyle either separately or from a parent trunk. The deep fascia is incised transversely as far laterally as the lesser saphenous vein, taking care to avoid injury to the cutaneous nerves, i.e the lateral cutaneous nerve of the calf and the anastomotic peroneal nerve (Fig 1000)

Behind the head and neck of the fibula the dissection is carried to the lateral head of the gastrocnemius (Fig 1001) This muscle is retracted pos teriorly exposing the origin of the soleus from the posterior aspect of the head and neck of the fibula Its nerve and vessel supply may be seen entering its superficial surface near its upper border The plantaris muscle is identified deep to the medial margin of the lateral head of the gastrocnemius. The plantaris is an important landmark since the junction of its belly and tendon lies directly over the major vessels and nerves These structures should be carefully freed from the surrounding tissues The popliteal artery is found lying upon the popliteus muscle and at its inferior border, and divides into the anterior and posterior tibial arteries. The finger is inserted beneath the fibrous arch of the soleus and this muscle may be lifted backward while its origin is reflected subperiosteally from the fibula. In freeing this muscle great care is exercised to avoid injury to its nerve supply and the anterior tibial vessels. This is the most critical and delicate stage of the dissection, as when the attachment of the soleus is released from the fibula, the anterior tibial vessels are exposed coursing forward through the interosseous membrane At this point the dissec tion is carried on to the anterior aspect of the upper end of the fibula. The anterior and posterior intermuscular septa are isolated and freely incised. A curved incision is also carried down to the bone across the head of the fibula and along the margin of the attachment of the peroneus longus, extensor digitorum longus and the tibialis anterior muscles to the lateral condyle of the tibia (Fig 1002) These attachments are deflected with a shaving of bone from the head of the fibula and the lateral condyle of the tibia As the muscles are turned forward and the common peroneal nerve lifted out of the way the interosseous membrane is reached from its anterior aspect. The anterior tibial vessels are met with again in the extensor compartment. The interosseous mem

brane and the tibialis posterior are separated from the upper end of the fibula. The popliteal vessel can now be retracted freely backward because its divisions have been freed at their points of fixation to the interosseous membrane and the fibrous arch of the soleus.

The next step is the division of the bone. A special retractor is passed around the medial surface of the neck of the fibula to protect the blood vessels and nerves. The common peroneal nerve is retracted upward and forward.

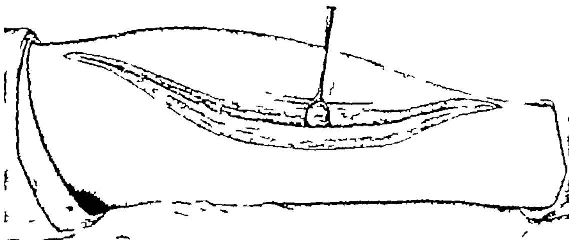


Fig. 1004.—Lengthening of tibia and fibula continued. Second stage. Line of curvilinear incision along posteromedial aspect of leg. (From Abbott, L. C., and Saunders, J. B. deC. M.: Ann. Surg. 110: 961, 1939.)

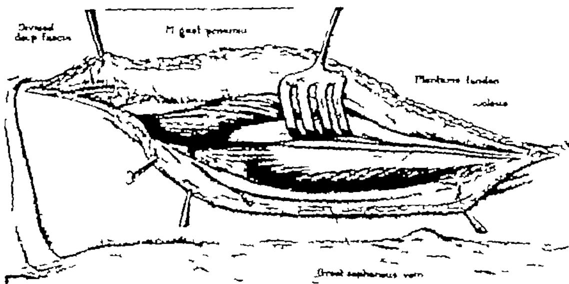


Fig. 1005.—Same as Fig. 1004. Second Stage. Deep fascia divided, gastrocnemius and soleus exposed. (From Abbott, L. C., and Saunders, J. B. deC. M.: Ann. Surg. 110: 961, 1939.)

The fibula is sectioned obliquely by a saw cut or by drill and osteotome. The osteotomy, about two and one-half inches in length, begins one-half inch below the tibiofibular joint and extends downward and laterally with a saw or if the operator prefers, a drill; a long oblique section is made through the outer cortex of the tibia. This section begins about one-half inch below the apex of the arch and passes downward and gradually forward upon the antero-

lateral surface of the tibia until it lies just below the tubercle of the tibia and posterior to the crest At this point a vertical section of the bone is continued down to the level of the junction of the middle and lower thirds of the bone At the lower end of this section, a transverse osteotomy is made through the crest and cortex of the subcutaneous surface of the tibia (Fig 1003)

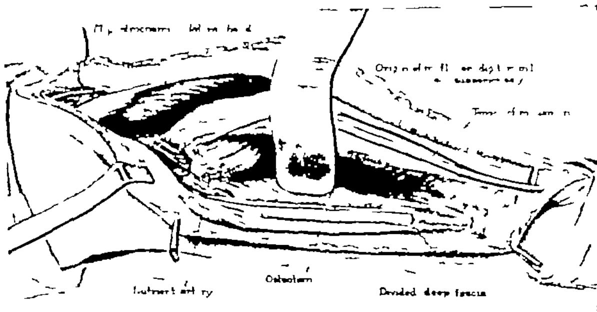


Fig. 1006.—Same as Fig. 1004 Second stage Osteotomy of tibia Note location of nutrient vessels. (From Abbott, L. C., and Saunders, J B. deC. M.: Ann. Surg. 110: 961 1939)

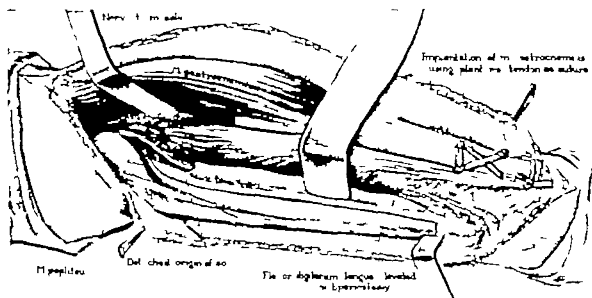


Fig. 1007 —Same as Fig. 1004. Second stage Osteotomy through posterior cortex of tibia extends from arch above to transverse osteotomy below paralleling osteotomy of lateral cortex f first stage, thereby completing separation of fragments. Note method of implantation of gastrocnemius, plantaris tendon being used as suture. (From Abbott, L. C., and Saunders J B. deC. M Ann. Surg. 110: 961. 1939)

The first stage is completed with suture of the detached origin of the muscles to the surrounding tissues to obliterate the dead space The anterior margin of the peroneus longus and the lateral margin of the soleus are sutured to prevent contact of the common peroneal nerve with the fibula.

"Second Stage.—The lengthening apparatus with the oblique pins is applied. With the knee flexed to 150° and externally rotated a curvilinear incision is made over the posteromedial aspect of the calf. It begins over the origin of the inner head of the gastrocnemius and ends at the junction of the middle and lower thirds of the leg where the tendons of the gastrocnemius and soleus merge to form the tendo achillis The summit of the convexity is placed one-half inch behind the medial border of the tibia. This avoids injury to the greater saphenous vein and the saphenous nerve (Fig 1004)

"A few veins are ligated as they cross the wound in the subcutaneous tissue The deep fascia is incised along the line of the skin incision. At the upper end of this fascial incision, a transverse division is made in the lateral direction through the deep fascia to the margin of the small saphenous vein. This transverse division of the fascia meets with the transverse division of the fascia made in the first stage At the lower margin of the wound a similar transverse incision of the fascia is made in an anterior direction until it meets the transverse division of the periosteum on the subcutaneous surface of the tibia at the level of the transverse osteotomy The fascial incision of the first and second stages of operation together with the division of the periosteum, complete an oblique circumferential section of the fascia and periosteum The tendon of the gastrocnemius is freed from the tendon of the soleus and sectioned obliquely (Fig 1005) This tendon is then implanted into the soleus at a higher level The distance upward of this transplantation is equal to the amount of length desired. Here it is secured by silk sutures which are reinforced by the tendon of the plantaris, this being utilized as a living suture (Fig 1007) With retraction of the gastrocnemius the popliteal vessels and the tibial nerves are freed to expose the origin of the muscles in the region of the fibrous bony arch formed by the upper ends of the tibia and fibula.

"The soleus muscle is detached at its origin from the posterior aspect and internal border of the tibia removing with it the superficial layer of the cortex (Figs. 1006 and 1007) As this muscle is turned downward, care should be taken not to injure the popliteal vessels, the tibial nerve and the branches of supply to the soleus and the tibialis posterior The nutrient vessels of the tibia, associated with the muscular branches of the soleus, are found entering the bone obliquely an inch or two below the oblique popliteal line on the lateral side of the posterior surface of the shaft. The insertion of the popliteus is reflected upward from the oblique line sufficiently to expose the posterior border of the tibia as it ascends to the apex of the arch. At this place the origin of the tibialis posterior and the attachment of the interosseous membrane are freed for a distance of one and one-half inches. In this denuded area a special retractor is inserted protecting the main vessels and nerves, while the bone is sectioned with a drill or saw beginning one-half inch below the tibiofibular arch. The osteotomy through the posterior cortex parallels at first the oblique line and then passes down just lateral to the medial border of its shaft to the junction of the middle and lower thirds where it meets the posterior extremity of the transverse osteotomy of the first stage of the operation (Fig 1007) Care is taken to insure that the fragments are free. The extension apparatus is now tightened until one can see a distinct separation of the fragments. The wounds are closed and the leg is supported in flexion.

After Treatment.—After operative reaction has subsided, usually a week, lengthening is instituted by tightening the thumb nuts on the two sides equally Measurements between the ends of the pins are made and recorded

daily with each adjustment This procedure is repeated until the leg attains the desired length The average daily gain is one sixteenth of an inch The entire traction period requires four to five weeks. Roentgenograms are made at regular intervals to check position and length

In the majority of cases, sufficient callus develops within ten to twelve weeks *to allow gradual extension of the knee* After extension is complete the apparatus is removed and a plaster cast applied from toes to groin

As a rule callus is adequate to permit weight bearing after four or five months. A Thomas walking caliper brace is then applied and is worn continuously for two or three months. Thereafter, the brace is continued for weight bearing until the callus is completely formed and the medullary canal reformed, usually nine to twelve months.

Lengthening of the Femur

Bost employs a method of femoral lengthening which is planned as in Abbott and Saunders method of leg lengthening to release the soft fibrous tissues surgically that postoperative lengthening may proceed with as few

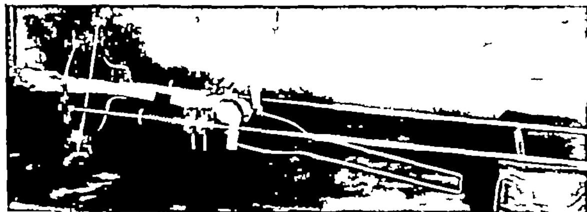


Fig 1008 —Bost apparatus used in lengthening of femur (From Bost, F C. Lectures on Reconstruction Surgery Ann Arbor 1944, J W Edwards.)

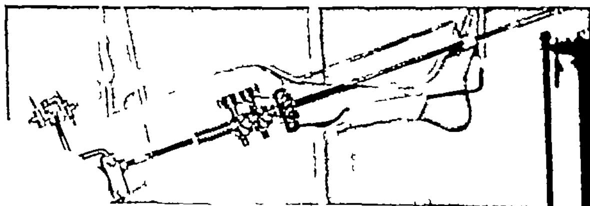


Fig. 1009 —Leg lengthening apparatus in place after operation, viewed from medial aspect. (From Bost, F C. Lectures on Reconstruction Surgery Ann. Arbor 1944, J W Edwards.)

complications as possible By this method he is able to secure two to three inches of lengthening The use of an accessory tibial graft is reserved for cases of nonunion and delayed union

Technic (Bost) —Through an anterolateral approach (p 173), the middle third of the femoral shaft is exposed and the periosteum elevated to the

minimum extent. A Z-type osteotomy is outlined the Z being about five inches in length and in the frontal plane The attachment of the adductor muscles is separated from the distal fragment, and the adductor magnus tendon is severed The fascia lata surrounding the outer part of the thigh, together with the iliotibial band, is divided at the level of the lower end of the osteotomy At the same level, the lateral intermuscular septum the linea aspera and the medial intermuscular septum are also divided. The septa are stripped downward from their attachments to the distal fragment while the lateral intermuscular septum is stripped upward along the linea aspera. The periosteal tube is divided one inch above the lower level of the osteotomy In this manner the resistance of the fibrous tissue is largely eliminated

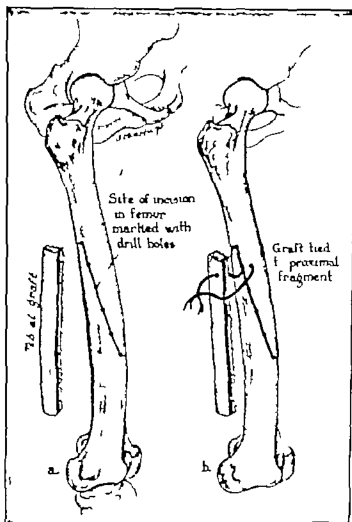


Fig. 1010.—Lengthening of femur (Compere) Line of osteotomy as viewed in lateral plane, and method of applying tibial onlay graft. (From Compere, E. L.: J Bone & Joint Surg. 18: 692, 1936.)

Before the osteotomy is completed, control pins are inserted through the bone One pin is inserted vertically and another obliquely through the upper third of the femur immediately below the level of the lesser trochanter Two additional pins are placed transversely through the lower third of the femur These pins are incorporated in a modified Thomas splint (Fig 1008) the ring receiving the upper pins while the lower pins are fastened to sliding bars. The pin holders permit adjustment of the pins in any direction, and thus, ac

curate control of the fragments Traction is then applied by means of springs incorporated on the side bars of the splint proximal to the two distal pins

After Treatment —The bone is lengthened at the rate of one-eighth inch daily until the desired or maximum lengthening is secured At the end of twelve to fourteen weeks the lengthening apparatus is replaced by a spica body cast incorporating one pin inserted below the knee Weight bearing is not permitted for at least six months and then only in a caliper type brace with a Thomas ischial bearing ring and a pelvic band This brace is worn until consolidation is complete and the medullary canal begins to reform

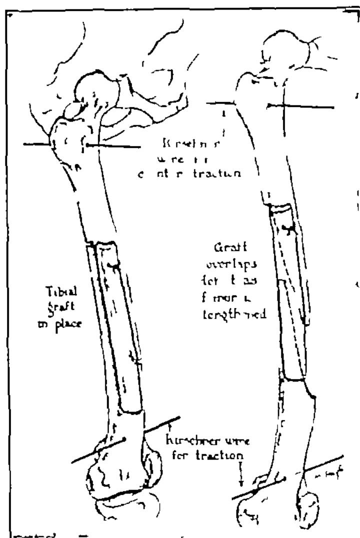


Fig. 1011.—Same as Fig. 1010 Tibial bone in place as onlay graft before and after lengthening. Illustrates splinting effect and advantage of obtaining stronger and more rapid bone union. (From Compere, E. L. J Bone & Joint Surg. 18: 692, 1936.)

Because of the frequency of delayed union or nonunion of the femur and the extremely long convalescent period Compere has augmented the Putti technic by the addition of a tibial graft This graft is attached at the proximal fragment and is of sufficient length to overlap continuously the defect created by the lengthening of the femur

Technic (Compere) —A Kirschner wire or a Steinman pin is inserted through the trochanter in the anteroposterior direction. An elastic bandage is then placed about the extremity from the toes to the groin and a tourniquet is applied above the pin. A longitudinal incision is made along the lateral

surface of the thigh and the femur is exposed by dissection between the muscles and the lateral fascial septum. To prevent devascularization, the periosteum is stripped only to the ends of the osteotomy site. Because of the possibility of producing a fracture at this point, the bone is severed obliquely rather than in Z-shape fashion the line of division usually being two inches longer than the amount of the increase in length desired. The outer cortex is cut with a motor saw drill holes are made at intervals of one half inch, and the osteotomy is completed through the medial cortex. A metal pin or wire is then inserted through the femur in the supracondylar region. A full thickness cortical graft is next removed from the tibia of the same extremity applied as an onlay graft to the lateral surface of the osteotomy site, and fixed by means of a suture through a drill hole in its proximal portion and the proximal fragment. Thus, as length is obtained, splinting of the distal fragment of the femur is maintained.

After Treatment.—A cast is applied including the body and opposite thigh and extending downward on the upper third of the thigh on the short extremity The proximal pin and a Thomas splint are also incorporated in the cast on the affected side. Traction and lengthening of the extremity are then instituted by means of a turnbuckle which connects the lower pin to the end of the splint in a manner similar to that of the Hoke type of skeletal traction. Immobilization by casts is discontinued and weight bearing begun after consolidation is complete.

LEG SHORTENING

Shortening of an extremity may be secured by epiphyseal arrest or by actual resection of bone from the tibia or femur In children with a growth expectancy of several years, the epiphyseal block has proved a simple but effective method of providing equality of length.

In adults we believe that in the majority of cases, shortening of the normal tibia and fibula or femur is more desirable than lengthening of the affected member The obvious disadvantage of operating upon a normal extremity in the presence of one already abnormal is recognized complications from the operative procedure in the normal extremity would be a catastrophe. Complications are no more likely to occur however than in any other elective orthopedic operation If the surgeon s technic is not sufficiently skilled to render complications, such as infection and nonunion remote possibilities, the procedure should not be undertaken.

Arrest of Epiphyseal Growth

Arrest of epiphyseal growth is a relatively simple operation, involving a minimum of risk both to the extremity and to life.

Prior to Phemister s introduction of surgical arrest of the longitudinal growth of bones, in 1933 little could be done to correct an inequality in length in growing children. The operation, which consists of fusion of the epiphyses at the lower end of the femur and lower or upper end of the tibia and fibula of the normal member is designed to retard growth in the normal extremity while the short member is allowed to grow that the length of the two may be equal when maturity is reached. This procedure is of course suitable only for children who have a growth expectancy of several years.

While the operation itself inhibits the growth of the longer limb, its effect on the relative lengths of the extremities is based upon the growth of the

shorter extremity Green and Anderson report that, in patients who had 75 per cent or less remaining musculature, the average retardation of the affected femur was 10 per cent and of the tibia 12 per cent

Hatcher, White Wilson and Thompson and Gill and Abbott have devised methods of calculating expected growth from a given epiphyseal plate. Some are more complicated and detailed than others, though each has certain virtues and defects Because of the numerous factors which influence bone growth a method of calculating growth expectancy cannot be devised with mathematical accuracy The use of the parents' measurements is not helpful in all cases as one cannot predict the final height of a child whose parents are of different heights Another factor to be considered is the patient's skeletal

CENTIMETERS OF CORRECTION TO BE DERIVED FROM ARREST OF DISTAL FEMUR OR PROXIMAL TIBIA PRELIMINARY CHART 1947

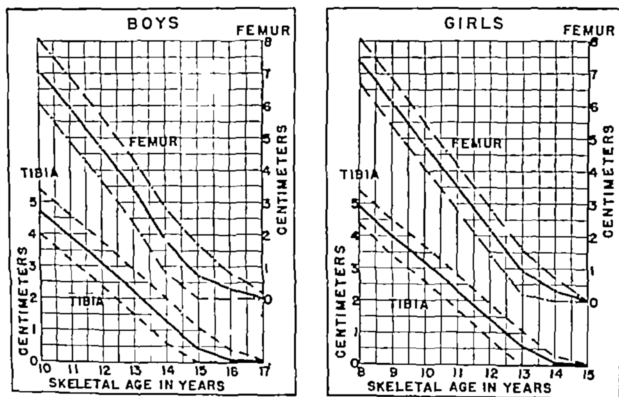


Fig. 1012.—From these tables prepared by Green and Anderson, amount of growth to be eliminated after epiphyseal arrest can be estimated. Central line represents average correction secondary lines, the useful range. Extremes are not indicated. (From Green, W T., and Anderson, M. J Bone & Joint Surg. 29: 659 1947)

age as compared with his chronologic age If a discrepancy of more than six months is found the skeletal age as determined from Todd's Atlas of Skeletal Maturation (Hand) should be used for all calculations. Hatcher has observed that arrests of epiphyseal growth are of little value in the female if menstruation has begun. Todd has shown that skeletal and sexual maturation are closely correlated regardless of the chronologic age the female begins menstruation at the average skeletal age of 13½ to 14 years

While many orthopedic surgeons employ only the conventional tape measurement in determination of leg length measuring from the anterior

superior spine to the medial malleolus, White, and Gill and Abbott stress the value of the more accurate roentgenographic determination of leg length. White employs flat plates taken on a regular Bucky table at a standard tube distance Roentgenograms of the pelvis are made with the patient lying on the Bucky table with the legs parallel and the feet forced firmly down against the transverse shelf at the foot of the table A central horizontal wire incorporated in a cassette serves as a datum line from which the distances to the tops of the femoral heads may be measured. The difference in heights of the femoral heads from the transverse foot shelf is the difference in leg length. The actual measurements are increased approximately 20 per cent by the roentgenograms though the same error will be present in all the films and thus will cancel itself. This method is accurate in any case wherein the hips are freely movable. If one hip is ankylosed the use of blocks of proper thickness must be inserted beneath the short leg before the legs can be placed in a parallel position for the roentgenogram.

Gill and Abbott employ a modification of Millwee s slit scanography as well as teleroentgenograms, for the determination of leg length. This is the most accurate method of determining leg length though special equipment is required

Absolute equalization of leg length is not invariably desirable A patient who must wear a long brace with a locked knee joint is usually better with one or two centimeters of shortening on the affected side On the other hand if a long leg brace is not needed the extremities should approach equal length in such a patient, correction is particularly indicated when marked shortening exists If a stabilization of the foot is planned at a later date one centimeter should be added to the proposed leg length to compensate for the reduction of the height of the foot which this operation produces.

If the discrepancy to be corrected is of material degree, growth should be arrested in one epiphysis at an early age and in the other at a later age. Error will thus be less likely if for some reason, such as a change in the pattern of maturation the original prediction should not be accurate.

In follow up of patients with asymmetry of the lower extremities, Green recommends that not only the discrepancy but also the actual lengths of the extremities, be recorded at regular intervals. He is thus able to determine the shortening and lengthening of the extremities and to calculate the percentage of inhibited growth. To permit a reliable estimate of skeletal maturity he advises that roentgenograms be made of the wrist at six and twelve-month intervals. Roentgenograms should also be made of the lower extremities postoperatively at the same intervals

The patients for whom it is easiest to plan are those in whom a single epiphysis has been destroyed because of some pathologic process. The corresponding growth center of the opposite extremity may then be eliminated on the assumption that subsequent growth will be equal in both extremities. In judging the degree of shortening which may be expected by epiphyseal arrest, White has found that three-eighths inch shortening per year during the period of growth may be anticipated following arrest of the lower femoral epiphysis. If the upper tibial and fibular epiphyses are resected, one-fourth inch shortening per year will follow the lower tibial and fibular epiphyses will also contribute one fourth inch shortening per year Green and Anderson have confirmed the accuracy of these observations In their study the yearly increment was found to be 1 3 cm. in the distal femoral epiphysis and 0 9

cm in the proximal tibial epiphysis Their calculations were made on the hypothesis that growth ceases at thirteen and three fourths years in girls and fifteen and three fourths years in boys. To determine the age at which an arrest should be done in a particular individual the amount of a shortening in centimeters is divided by the yearly increment of the femur (1.3), the tibia (0 9), or the combination of the two (2.2) to determine the number of years required for the equalization This figure is then subtracted from the age of 13¾ in girls or 15¾ in boys to determine the age at which the arrest is indicated The patient s age is of course checked against Todd's maturation age and as stated above if there is a discrepancy of more than six months the skeletal age should be used instead of the patient's chronological age If only a moderate retardation of growth is indicated the growth arrest may be performed above or below the knee depending upon whether the shortening of the opposite extremity is greater in the thigh or knee

Green and Anderson have also devised a method of predicting the effect of epiphyseal growth arrests, based upon a cumulative series of the annual increments in the growth of the long bones of the lower extremities between consecutive ages. Their chart (Fig 1012) gives a central line representing the average correction and secondary lines denoting the useful range In using this chart they advise a modification of the position between the ranges in the individual case as for example, in a tall person with long legs, the correction should approach the upper limits of the predicted amount, while in a short individual it should approach the lower range. Likewise, an individual with a high percentage of inhibited growth in the affected lower extremity would be expected to receive less correction than one whose coefficient of inhibited growth is less and accordingly the predicted amount should be adjusted toward the lower figure for the age If the patient has not had accurate measurements long enough for the percentage of retarded growth to be determined it may be approximated by relating the existing shortening to the estimated growth since the onset of the disease

The possibility that the epiphysis will not be symmetrically fused, with a consequent genu varum or valgum or genu recurvatum deformity should be explained to the parents. Campbell observed two cases of slight knock knee following this operation the deformity was not sufficiently severe to warrant surgical correction. Another patient developed a definite genu recurvatum deformity after three years of growth subsequent to epiphyseal arrest by the Phemister method. This is explained by an error in technic. As the approach to the lateral surface of the tibia is somewhat more difficult than that to the medial side there is a tendency to expose the anterolateral aspect of the bone and arrest the epiphysis in this area. In the last case in question, only the growth of the anterior portion was arrested with the result that the posterior portion continued to grow producing an anterior tilt to the articular surface of the tibia and a consequent genu recurvatum though relatively little disability

Exposure of Epiphyseal Cartilages of the Knee and Ankle Joints

Abbott and Gill have developed anatomic approaches to the epiphyseal plates about the knee and ankle joints which permit exposure of the plates with a minimum of soft tissue damage.

Lateral Exposure of Lower Femoral, Upper Tibial and Upper Fibular Epiphyseal Plates (Abbott and Gill) —With the knee supported at 150 de-

grees the anatomic landmarks are prominent and the hamstring muscles are relaxed. Beginning two and one half inches proximal to the lateral condyle of the femur, the skin is incised directly over the interval between the biceps tendon and the iliotibial band thence distal and posterior to the head of the fibula, and then gently forward onto the lateral surface of the leg (Fig 1013) The lateral intermuscular septum is developed to the linea aspera retracting

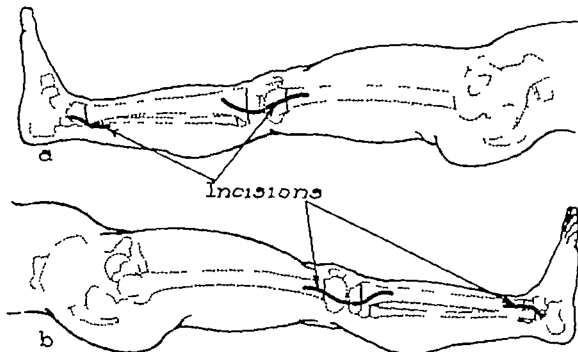


Fig. 1013.—Surgical approaches to epiphyseal cartilages at knee and ankle. *A*, Medial aspect of leg. *B* Lateral aspect of leg. (From Abbott, L. C., and Gill, G. G.: Arch. Surg. 46 591 1942.)

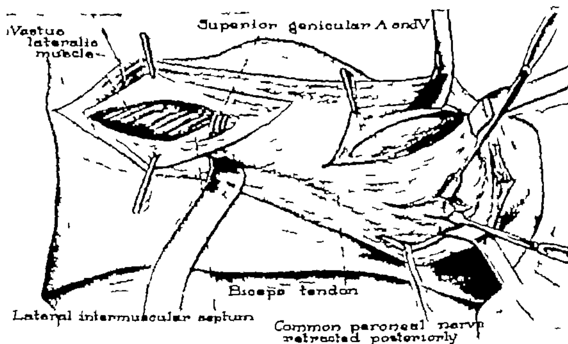


Fig 1014.—Same as Fig. 1013. Lateral aspect of knee. Exposure of lower femoral and upper tibial and fibula epiphyseal plates. (From Abbott, L. C., and Gill, G. G. Arch. Surg. 46 591, 1942.)

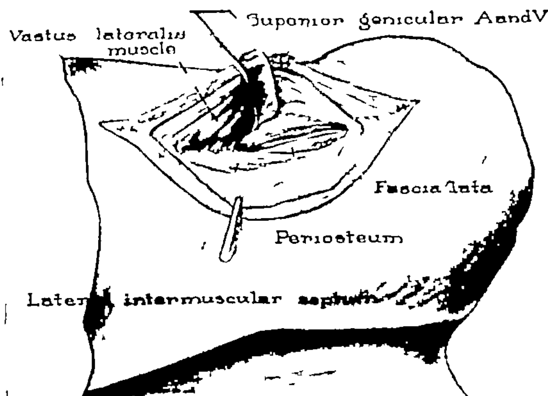


Fig. 1015.—Same as Fig. 1013. Detail of approach to lateral aspect of lower femoral epiphysis. (From Abbott, L. C., and Gill, G. G. Arch. Surg. 44: 591, 1942.)

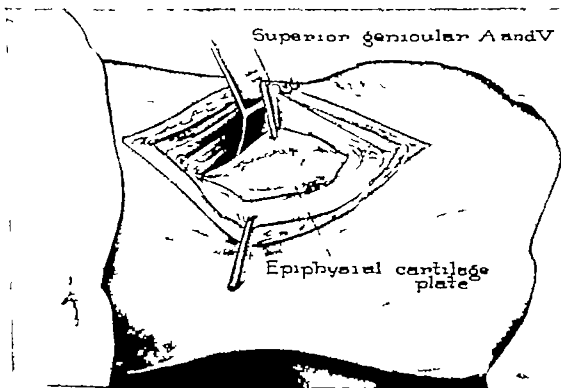


Fig. 1016.—Same as Fig. 1013. Incision of periosteum, lateral aspect of distal end of femur, periosteum elevated, revealing cartilaginous plate. (From Abbott, L. C., and Gill, G. G. *Arch. Surg. 44: 591, 1942.*)

the vastus lateralis muscle forward This exposes the lateral surface of the femur at its junction with the lateral condyle This point marks the site of the epiphyseal cartilage The superior lateral genicular vessels are divided and ligated The periosteum is incised longitudinally subperiosteal dissection exposes the epiphyseal plate which appears as a thin white transverse cartilaginous line in contrast to cortical bone

The distal limb of the lateral incision is now developed to expose the upper tibial and upper fibular epiphyses. Prior to this procedure the common peroneal nerve should be identified and isolated behind the biceps tendon Thereafter an incision is made directly down to the head of the fibula over its anterior and medial aspects Subperiosteal dissection exposes the epiphyseal plate. The lateral aspect of the upper tibial epiphysis is visualized by reflecting the origin of the extensor muscles from the arcuate line

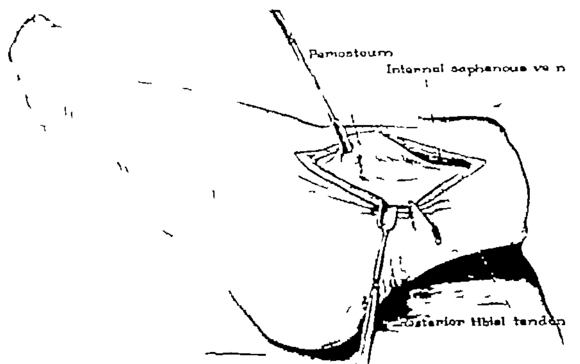


Fig. 1019—Approach to medial aspect of lower tibial epiphyseal plate. (From Abbott, L. C., and Gill, G G Arch. Surg. 46: 591, 1943)

Medial Exposure of the Lower Femoral and Upper Tibial Epiphyseal Plates (Abbott and Gill) —A medial longitudinal incision five inches in length is centered over the adductor tubercle This prominence marks the junction of the epiphysis and diaphysis of the femur The distal limb of the incision crosses the condyle of the femur and curves gently forward in line with the tendon of the sartorius. After incision of the deep fascia the anterior surface of the intermuscular septum is followed to the bone, the vastus medialis being retracted anteriorly The epiphyseal plate is overlapped by the attachment of the capsule and the reflected synovial membrane of the knee joint. After division and ligation of the genicular vessels the epiphyseal plate is exposed through a longitudinal incision in the periosteum further developing the exposure by subperiosteal dissection

The medial aspect of the upper tibial epiphysis is visualized by incising the deep fascia on the anterior margin of the sartorius tendon the anterior edge of the tibial collateral ligament is identified and retracted posteriorly

Fig. 1017.—Combined approach to medial aspect of lower femoral and upper tibial epiphyseal plates. (From Abbott, L. C., and Gill, G. G.: Arch. Surg. 46: 591, 1943.)

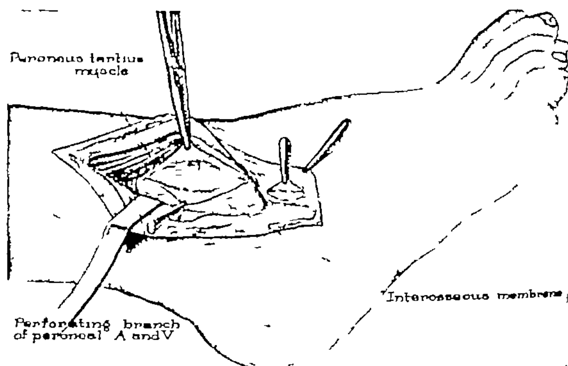


Fig. 1018.—Approach to lateral aspect of lower tibial epiphysis, and epiphyseal plate of lower end of fibula. (From Abbott, L. C., and Gill, G. G.: Arch. Surg. 46: 591, 1943.)

the vastus lateralis muscle forward This exposes the lateral surface of the femur at its junction with the lateral condyle This point marks the site of the epiphyseal cartilage The superior lateral genicular vessels are divided and ligated The periosteum is incised longitudinally subperiosteal dissection exposes the epiphyseal plate which appears as a thin white transverse cartilaginous line in contrast to cortical bone

The distal limb of the lateral incision is now developed to expose the upper tibial and upper fibular epiphyses. Prior to this procedure the common peroneal nerve should be identified and isolated behind the biceps tendon Thereafter an incision is made directly down to the head of the fibula over its anterior and medial aspects Subperiosteal dissection exposes the epiphyseal plate The lateral aspect of the upper tibial epiphysis is visualized by reflecting the origin of the extensor muscles from the arcuate line

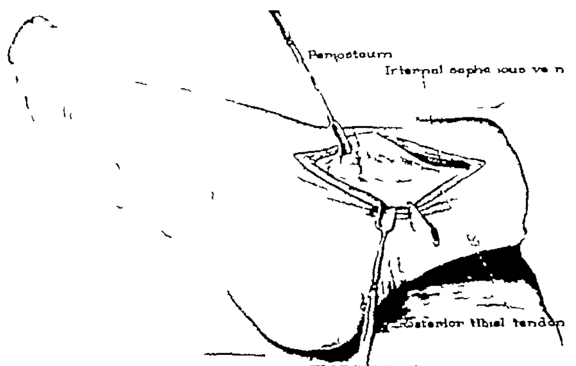


Fig. 1019—Approach to medial aspect of lower tibial epiphyseal plate. (From Abbott, L. C., and Gill G G Arch. Surg. 46: 591, 1943)

Medial Exposure of the Lower Femoral and Upper Tibial Epiphyseal Plates (Abbott and Gill)—A medial longitudinal incision five inches in length is centered over the adductor tubercle This prominence marks the junction of the epiphysis and diaphysis of the femur The distal limb of the incision crosses the condyle of the femur and curves gently forward in line with the tendon of the sartorius After incision of the deep fascia the anterior surface of the intermuscular septum is followed to the bone the vastus medialis being retracted anteriorly The epiphyseal plate is overlapped by the attachment of the capsule and the reflected synovial membrane of the knee joint. After division and ligation of the genicular vessels the epiphyseal plate is exposed through a longitudinal incision in the periosteum further developing the exposure by subperiosteal dissection

The medial aspect of the upper tibial epiphysis is visualized by incising the deep fascia on the anterior margin of the sartorius tendon the anterior edge of the tibial collateral ligament is identified and retracted posteriorly

The epiphyseal plate is exposed directly anterior to this ligament, through a longitudinal incision. The epiphyseal plate is located about one-half to three-fourths of an inch distal to the articular margin of the tibia

Exposure of the Epiphyseal Plates of the Distal End of the Tibia and Fibula (Abbott and Gill) —*The lateral aspect of the lower tibial epiphysis,* and the distal fibular epiphysis are exposed through an anterolateral incision some two to three inches in length. The incision follows the anterior margin of the fibula. The distal fibular epiphysis is exposed by subperiosteal dissection about one-half inch proximal to the tip of the bone. Retraction of the peroneus tertius muscle from its origin on the fibula and the adjacent interosseous membrane exposes the tibia. The perforating branches of the peroneal artery are divided and ligated if necessary The longitudinal incision exposes the epiphyseal plate of the tibia at a point of about one-half inch proximal to the margin of the ankle joint.

The medial side *of the tibial epiphysis* is exposed by *a longitudinal incision along the posterior border of the tibia and internal malleolus. The* epiphysis lies three fourths to one inch proximal to the tip of the malleolus.

ARREST OF EPIPHYSEAL GROWTH

Prior to epiphyseal arrest of the lower femoral epiphysis and upper tibial epiphysis, anteroposterior roentgenograms should be made of the knee to determine the exact contour of the epiphyses. The epiphyseal plates do not lie at an *exact transverse plane to the longitudinal axis of a bone* The lower femoral epiphysis is usually V-shaped as viewed from the front the upper tibial epiphysis is more or less an inverted V The angular planes of the epiphyses flatten out to a transverse plane with maturation.

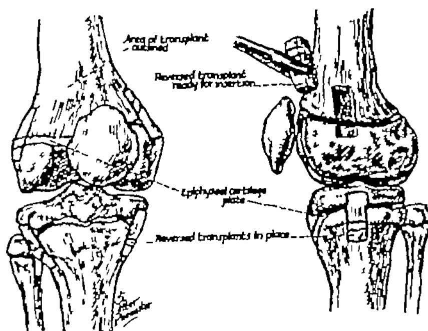


Fig. 1020 —Phemister technic *of* epiphyseal arrest. Transplants reversed and cartilage chiseled out of epiphyseal plate. (Redrawn from Phemister D B.) J. Bone & Joint Surg. 15: 1, 1933.)

Technic (Phemister) —After exposure of the epiphyseal plate, a rectangular section of cortex 3 cm. in length, and 1 1.5 cm. in width, is excised by means of an osteotome crossing the cartilaginous line and including about

1 cm of the epiphysis. On each side of the section removed the cartilaginous disc is chiseled out anteriorly and posteriorly a distance of 3 to 5 cm and to a depth of approximately 1 cm The rectangular transplant is reinserted into the trough with its ends reversed A similar procedure is repeated on the opposite condyle

In the case of the fibula, the cartilaginous disc is completely excised in an anteroposterior plane and removed, an osteotome and a small curette being used for the purpose, or, a portion of the disc may be excised and the small metaphyseal graft shifted upward across the epiphyseal line Defects from removal of the cartilaginous plate are filled in with small bone chips.

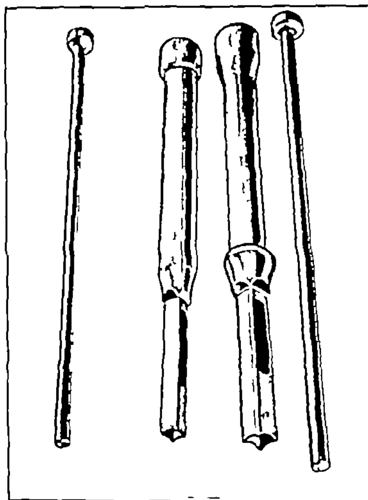


Fig. 161L.—Square hollow chisels devised by Dr J Warren White to facilitate fusion of epiphyses.

After Treatment—The extremity is immobilized in a long night-splint, or posterior gutter splint, for a period of three weeks. Usually by the end of one month walking may be allowed.

Technic (Green)—The Phemister procedure is modified as follows the grafts removed equally distant from the anterior and posterior surfaces of the bone, are one inch in width and approximately three-fourths of an inch in depth the grafts are sufficiently long to extend well beyond the epiphyseal plate into the epiphysis and at least one inch into the diaphysis. With a one-eighth inch drill the epiphyseal plate is carefully explored throughout its entire extent. With a small drill, the cartilaginous plate may be followed ac

curately by the feel of the drill. Subsequently the epiphyseal plate is obliterated with a three-sixteenth inch or one-fourth inch drill. From the bed of the diaphyseal portion of the graft, slivers of cancellous bone are re-removed and inserted into the obliterated plate so as to fill it completely. The rectangular grafts rotated 180 degrees are reinserted so that cortical bone impinges upon cortical bone, the grafts fitting snugly and smoothly.

White employs a hollow chisel which greatly facilitates the operation for arrest of the epiphyses, permitting a more accurate and complete resection of the epiphysis and materially decreasing the operating time. This instrument, which resembles in principle an apple corer, is constructed from a wood worker's square mortising chisel, being one-half inch square at the end. An obturator is constructed of a rod of similar length, large enough to fit loosely in the opening of the chisel. By this means a section of the epiphysis is removed efficiently and rapidly and with the least possible injury.

Technic (White).—After proper exposure of the epiphyseal line on both sides, the square mortising chisel is made to straddle that structure diagonally so that two of the points are forced into the line and one into the bone on each side. The chisel is then driven into the bone to a depth of three-fourths inch or more, depending, of course, upon the size of the child. If desired, the course of the epiphyseal disc may be accurately ascertained by probing with an ordinary straight skin needle before the chisel is inserted. The chisel is then loosened and extracted as one would remove a post from the ground, the bone plug being withdrawn in the chisel as an apple is cored. This plug is allowed to remain in the instrument until needed. With a small curette the epiphyseal disc is erased as thoroughly as possible. Since the spaces on each side are only thinly separated, the portion of cartilage between is removed also with a curette. The plug is then taken from the instrument and replaced in the square hole, being rotated through an angle of 90 degrees so the epiphyseal line in the plug of bone will be in the longitudinal axis of the leg and the epiphysis will be bridged by a section of solid bone. The plug is tapped lightly into place and the wound is closed.

Epiphyseal Arrest by Stapling

Haas has found that epiphyseal growth may be temporarily arrested by the use of a wire encircling the epiphyseal plate. Further growth from the plate takes place upon the removal of the wire. Blount has substantiated Haas' work, though he has used staples instead of an encircling wire. The staples are similar to those employed by Burns for the maintenance of position and apposition following foot stabilization arthrodesis and osteotomy. This procedure is designed to arrest growth by mechanical means without destroying the epiphyseal plate; when the desired deformity or length inequality has been sufficiently corrected, the staples may be removed and growth from the epiphyseal plate will continue. The method should not be used indiscriminately, nor should its general use be encouraged until longer follow-up studies are available and until its limitations and indications are more definitely determined. Quite possibly the procedure will have a wide range of usefulness.

The following discussion of epiphyseal arrest by stapling has been prepared by Blount, whose experience with the method has been wider than that of others.

In the older books on the open reduction of fractures there are numerous references to the use of staples, and Burns in this country has used them successfully in arthrodesis and the maintenance of osteotomies as well as in the operative treatment of fractures. They are equally effective in the arrest or retardation of the growth of an epiphysis if correctly used. If constructed or inserted improperly they will bend, break or pull out. Staples made of $\frac{3}{32}$" rods of type 302 chrome nickel stainless steel with legs $\frac{3}{4}$" long and cross members $\frac{5}{8}$" long are satisfactory. At least two must be used on either side of an epiphysis for complete arrest and in older children it is better to use three for the growth pressure is tremendous. Cessation of growth at the epiphysis following stapling is complete and immediate. Staples have been used on one side of an epiphysis and the conventional growth arrest operation on the other with equal efficiency.

The frequent occurrence of a back knee and knock knee deformity in poliomyelitis may be effectively combated by placing three staples in the medial femoral condyle far posteriorly. Similarly the knock knee and pronated foot produced by overgrowth of the tibia in chronic osteomyelitis may

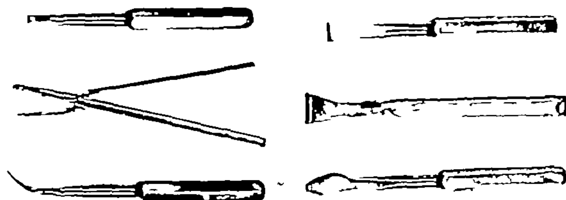


Fig. 1022.—Instruments employed in epiphyseal stapling. (1) Set to drive staple "home". (2) tong to hold staple when starting. (3) crowbar used in extracting staple. (Courtesy of Dr W P Blount.)

be effectively combated by stapling the medial aspect of the proximal end of the tibia. Inequality of the leg length from any cause may be corrected earlier by stapling than would be wise by permanent epiphyseal growth arrest by bone graft. It has been definitely proved that the epiphyses start to grow again when the staples are removed and the rate of growth in the cases which have been followed appears to be the same after removal of the staples as on the unaffected side. There has not been a premature closure of the epiphysis in the cases which have been stapled as long as three years but longer restraint of the growth cannot be recommended if resumption of the normal rate is to be anticipated.

Technic (Blount) — The epiphyseal plates are exposed through straight lateral and medial incisions for a single epiphysis slightly curved ones are used for exposing both tibial and femoral epiphyses. A one inch longitudinal incision is made in the periosteum along the central axis of the bone. A short perpendicular cut is made on the end nearest the knee joint. The periosteum is raised with a curved chisel or periosteal elevator often with a flake of bone

It is retracted posteriorly and the posterior staple is inserted so that it centers over the epiphyseal line. Due allowance must be made for the undulations of the epiphyseal line as seen in the original roentgenogram. Usually the staple must be placed slightly farther distal on the femur than would appear necessary, and at the proximal end of the tibia, the staple must be placed somewhat proximal (Fig 1023)

'An efficient holder will be found useful in inserting the staples accurately and rapidly A 'set is convenient in driving them completely home. Most important of all is to have a small extractor shaped like a crowbar for with this, extraction is easy (Fig 1022)

"A second staple is inserted across the epiphyseal growth plate on the opposite side The position is then verified by roentgenograms in the anteroposterior projection. If the location of the first staple on each side is correct, it is driven in all the way A second staple is placed about one-fourth of an inch anterior to the first. In older children, it is desirable to use three staples in growth arrest. In older children it is always necessary to use three or more unilaterally to correct angular deformity (Fig 1023*B*) If the first staple is not ideally placed, a correction is made in driving the second and the third The first is then pulled out and placed at the same level as the other ones Check up roentgenograms must be made after any change If staples are to be placed far posteriorly in correcting back knee deformities it is wise to make a lateral roentgenogram as well

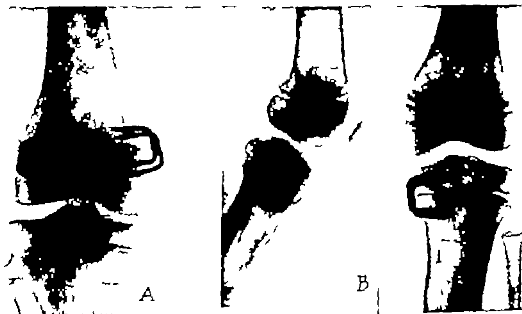


Fig 1023 —Epiphyseal arrest by stapling (Blount) *A* Equalization of leg length accomplished by stapling distal femoral epiphysis of long leg *B*, Overgrowth of tibia with valgus of knee corrected by stapling medial aspect of proximal tibial epiphysis. Case of chronic osteomyelitis of tibia. (Courtesy of Dr W P Blount.)

When the growth is arrested at the proximal end of the tibia, it is necessary to curette the epiphysis at the proximal end of the fibula.

After Treatment — A long cylinder cast extending from ankle to groin (and including the foot in young children) is applied for three weeks to encourage healing of the wounds without stretching of the scars. The child is permitted to walk with or without crutches as soon as he wishes. '

Shortening of the Lower Extremity by Resection of the Tibia

If the shortening to be compensated for is largely below the knee the operation should, of course, be performed below the knee, that the knee levels may be more nearly equal Other factors being equal femoral shortening is preferable to shortening of the tibia for several reasons There is only one bone with which to contend in the femoral shortening that bone is deeply embedded in the musculature of the thigh and the cosmetic result from a simple femoral overlap procedure is equally as good as when a complicated difficult, and prolonged operation such as the step-cut shortening is performed Further, the incidence of nonunion and delayed union is less following a simple overlap femoral shortening and the thigh muscles will recover normal tension and strength more quickly and easily than will the muscles of the leg following a shortening procedure. Not more than two inches should be removed from the tibia otherwise, the muscles and tendons of the foot and ankle may be shortened to such a degree that normal tension is not recovered and strength is impaired commensurately

Technic.—A six inch longitudinal incision is made over the anteromedial aspect of the tibia. The periosteum is split from this surface throughout the length of the incision and the bone is severed in the center of the incision by means of a Gigli saw With a motor saw, the medial half of the proximal fragment is removed and in like manner, the lateral half of the distal fragment, thus forming a step-cut. The resected bone is preserved in a sterile pan, to be used as grafts. A second incision is then made on the lateral aspect of the leg over the middle and lower thirds of the fibula, exposure of the fibula at this point is less difficult than over the upper two-thirds of the leg The periosteum is split for a distance of two inches and the bone is divided A step-cut of this small bone is unnecessary instead, the fragments are so placed as to overlap Simultaneously, the raw surfaces of the step-cut in the tibia are approximated. The fragments of the fibula are held in place by a wire loop inserted through an apposing drill hole in each fragment, or passed completely around both fragments. This serves to immobilize the tibial fragments partially while the following procedure is carried out to insure fixation.

The lateral aspect of the step-cut areas of the tibia is exposed, and the fragments are fixed with two metal screws. The remaining fragments of bone are cut into toothpick grafts and placed across the osteotomy site on the lateral and posterior surfaces of the tibia.

After Treatment.—A plaster cast is applied from the crest of the ilia to the toes, holding the knee in flexion and the foot in slight equinus. To allow for postoperative swelling a window is cut in the cast from above the knee to the toes. Three to four weeks postoperatively this cast is replaced by a similar snugly fitting cast. If union is firm at the end of eight weeks, the cast is removed and immobilization continued by the use of a brace with a drop ring catch at the knee and a leather lacer corset which completely encases the lower leg Weight bearing is then gradually resumed and physical therapy and active and passive exercises are instituted to increase function of the knee and ankle Usually all apparatus may be discarded after four to six months.

Although there may be some residual weakness of the muscles for a few months from this amount of shortening their power will ultimately be satisfactory

Shortening of Lower Extremity by Resection of Femur

By resection of the femur, the length of the extremity may be decreased three to four inches without deleterious effect on the musculature.

In considering the femoral shortening for children, one must remember that the operation itself is a stimulus to growth and not infrequently an additional full inch of growth takes place, nullifying possibly 50 per cent of the shortening obtained. Thus, it is advisable to defer leg shortening until the end of the growth period, or, if the shortening is to be carried out during this period arrests should be performed at the same time.

Technic.—A longitudinal anterolateral incision is made over the lower extremity of the thigh (p 173) exposing the lower half of the femur and the periosteum is completely elevated for a distance of six inches. The femur is severed by means of a Gigli saw and the fragments are delivered from the wound With a motor saw three inches of the bones are resected from both the lateral half of the distal fragment and the medial half of the proximal fragment, thus forming a step-cut. The two fragments are approximated and fixed with metal screws, the latter being staggered in position. The remaining bone should be cut into matchstick grafts and placed around the circumference of the femur as barrel stave grafts.

After Treatment.—With the knee and hip in flexion, a plaster cast is applied from the nipple line to the opposite knee and to the toes on the affected side. At the end of eight weeks the cast is removed. If the osteotomy site is united, a Thomas caliper brace with a leather lacer corset encasing the thigh is fitted. A drop ring catch is attached at the knee to maintain rigidity on walking and permit flexion on sitting Physical therapy with active and passive motion, is begun to stimulate motion of the knee and hip and increase muscle power After six months, all apparatus is discarded.

If slight motion is still present on removal of the cast, immobilization is continued in a new cast extending from the nipple line to the toes on the affected side

After experience with over one hundred femoral shortenings, White now osteotomizes the femoral shaft without removal or reshaping of the bone. In tall individuals, the bone may be overlapped as much as four inches in shorter individuals overlapping to this extent may result in some weakening of the thigh musculature Ordinarily compensatory shortening of the musculature will take place within two months and by this time consolidation of the overlap site will be sufficient and the leg may be held extended against gravity

White feels that the site of election for femoral shortening is in the middle third of the femur here a simple overlap procedure may be carried out well away from the knee and lateral bowing force is less likely to produce a coxa vara or lateral bowing than if the osteotomy is performed in the proximal third. Step-cut shortening of the femur is technically a difficult procedure, is time consuming devitalizes the bone by the extensive periosteal stripping which is required, and weakens the fixation Further there is always the possibility that the tongue of one of the fragments may fracture at the time of operation or even during the postoperative period, before consolidation is complete. One advantage of the step-cut operation, however is that the cubic contents of the thigh is not increased this permits easier closure of the wound in heavily muscled individuals, in whom closure may present a real problem if more than two inches of shortening is to be overcome This advantage fails to outweigh the disadvantages of the step-cut.

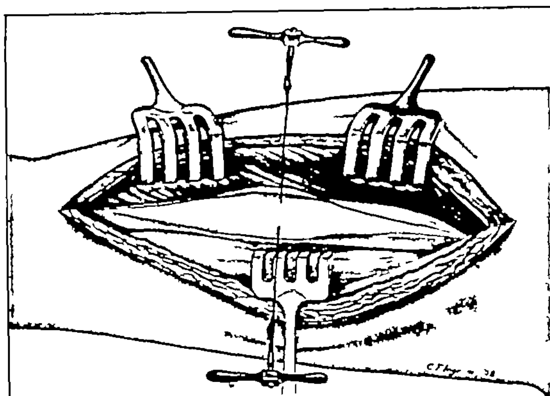


Fig. 10 4.—Shortening of femur by Z plastic step-cut (Campbell) Exposure of femur shaft divided with Gigli saw

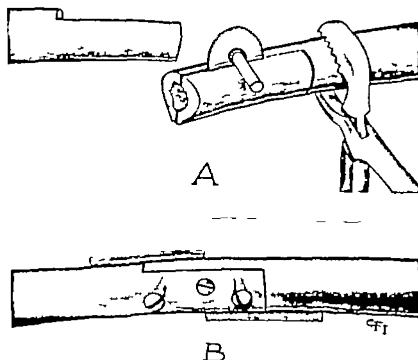


Fig 10 .—Same a Fig. 1024 A Stepcut of desired length of shortening made in each fragment with motor saw B Fragments apposed and fixed with metal screws. Detached fragments of bone placed as barrel-stave grafts about femur

Technic (White).—Through an anterolateral approach of approximately twice the length of the desired shortening, the femoral shaft is exposed subperiosteally An oblique femoral osteotomy is performed, being so placed to permit the overriding fragments to fit properly and the points of the osteotomy to lie against the opposite shafts. White prefers that the proximal fragment lie anterior and lateral to the distal fragment. A Gigli saw may be used, but multiple drill holes connected with chisel cuts is preferable. Care should be taken to prevent the medial surface from splitting in order that four intact bone cortices will be available for screw fixation. The fragments are held in the desired overlapped position by a Lowman clamp while three or four long metal screws are inserted across the four cortices. The screws should be staggered in position rather than placed in the same plane

After Treatment.—With the hip and knee of the affected side in a position of 150 degrees' flexion a plaster spica cast is applied extending from the nipple line to the toes on the affected side and to the knee of the opposite side. As a rule, consolidation is sufficiently advanced after two months to allow removal of the cast. Mobilization exercises for the knee are then instituted. Weight-bearing is allowed when the roentgenogram demonstrates complete consolidation

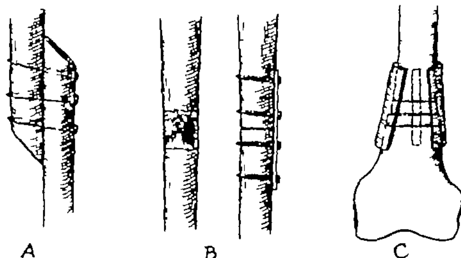


Fig. 1026.—Shortening of femur A Technic of White. Femur divided obliquely and fragments overlapped. Fixation with three screws. B Suggested modification of Fassett procedure. Shaded area represents portion of bone resected to produce desired shortening. Fragments apposed and fixed by metal or bone plate and four screws. C Technic of Robert D. Moore, intramedullary graft being used for fixation. Excised fragments serve as barrel stave grafts.

White states that the excess amount of bone in the thigh at the overlapped area is not an objectionable feature, since within a few years, at least in a growing child, the normal architecture is re-established and the site of operation is hardly visible in the roentgenogram.

Fassett, in 1918 advocated a technic for use in children and young adults. A segment of bone of appropriate length was removed from the shaft of the femur the fragments approximated, and apposition and alignment maintained by means of a plate or bone graft (Fig 1026*B*)

R. D Moore has recently advocated supracondylar shortening of the femur He cites the advantages of this site as follows consolidation of the osteotomy takes place rapidly the approach and operation are relatively simple disturbance of the quadriceps mechanism is less by the lateral approach than by muscle splitting approaches in the middle third of the thigh there is less

tendency to postoperative angulation because of the distance of the osteotomy site from the heavy hip flexor and adductor muscles, the deforming influence of the gastrocnemius on the distal condylar fragment is easily controlled by postoperative flexion of the knee and motion in the knee promptly returns after operation

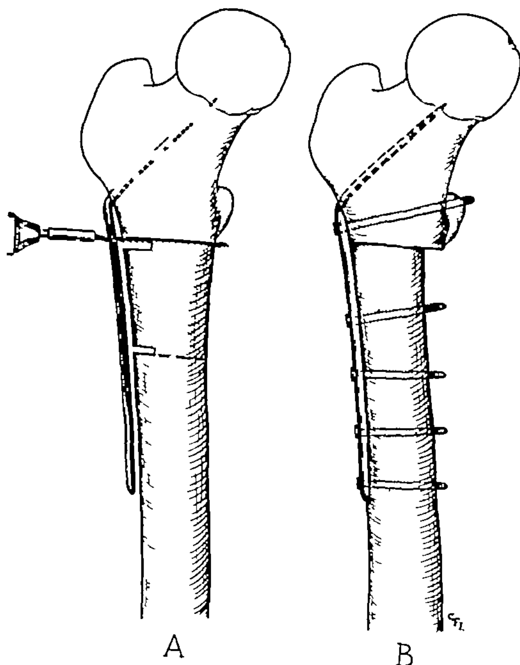


Fig 1027—Shortening of femur by technic of Blount. Osteotomy through lateral cortex completed prior to insertion of Blount blade plate. *A* Blade plate inserted and femur being sectioned with reciprocating saw *B* After completion of osteotomy, fixation secured by screws through blade plate and shaft. Grafts from excised segment of bone used to bridge osteotomy site.

Technic (Moore) —Through a seven inch lateral incision just anterior to the lateral intermuscular septum the lower third of the femur is exposed. The lowermost anterior perforating branches of the profunda femoris artery and vein are ligated and divided. The periosteum is elevated from the meta physis over the segment of bone to be excised and the segment is marked with

a chisel. The distal osteotomy is made first by means of a Gigli saw To facilitate the proximal osteotomy the shaft of the femur is then displaced outward into the incision. The resected segment is then divided longitudinally into several pieces and one portion is used as an intramedullary graft. One half of the length of this graft is inserted into the medullary canal of the proximal fragment and secured with a transfixion screw The remaining pieces of the resected segment are used as simple onlay grafts to bridge the osteotomy site circumferentially

After Treatment.—The hip and knee are placed in 150 degrees of flexion and a single spica cast is applied from the toes to the nipple line At the end of eight weeks if consolidation is sufficiently advanced the spica is removed and a long leg walking cast is applied

Blount has performed the femoral shortening operation in the subtrochanteric region of the femur using the single angled blade plate as internal fixation

Technic (Blount).—The patient is placed on the fracture table with gentle traction on each leg Through a straight lateral approach, the upper third of the femur and the lateral aspect of the trochanteric region are exposed periosteally The blade plate is inserted through the base of the greater trochanter into the femoral neck and a metal screw is passed through the proximal hole of the plate and both cortices of the femur A segment of the femur of the desired length is excised just distal to the lesser trochanter (Fig 1027*A*) by means of either the Gigli saw or a motor saw with a reciprocating blade. The traction is released and the bone ends firmly approximated the blade-plate being used to control the proximal fragment three or four screws are inserted through the holes in the plate and through drill holes in both cortices of the femur (Fig 1027*B*) The segment of femur which has been removed is cut into matchstick grafts and these are laid around three-fourths of the circumference of the femur at the osteotomy site, to serve as supplementary grafts.

After Treatment.—A spica type muslin dressing is employed postoperatively No other immobilization is necessary Blount allows these patients to begin walking on crutches after about three weeks, and encourages early motion in the knee Unrestricted weight bearing is permitted when consolidation is complete

References

Abbott, L. C The Operative Lengthening of the Tibia and Fibula, J Bone & Joint Surg 9 128 1927

— The Operative Lengthening of the Tibia and Fibula, West. J Surg 39 513 1931

— Lengthening of the Lower Extremities, California & West. Med. 36 6, 1932.

Abbott, L. C., and Crego C H. Operative Lengthening of the Femur South. M. J 21: 823 1928

Abbott, L. C. and Gill G G Surgical Approaches to the Epiphyseal Cartilages of the Knee and Ankle Joint, Arch. Surg 46 591 1943.

Abbott, L. C., and Saunders, J B. deC. M The Operative Lengthening of the Tibia and Fibula, Preliminary Report on Further Development of Principles and Technic, Ann. Surg 100 961 1939

von Baeyer Described by Peabody in personal communication.

Baldwin B. T The Physical Growth of Children from Birth to Maturity University of Iowa Publications, 1 1921

Bancroft, Frederic W., and Murray Clay Ray Surgical Treatment of the Motor Skeletal System, Philadelphia, 1945 J B. Lippincott Co.

Barr J S., Freiberg J A Colonna, P C., and Pemberton P A.: A Survey of End Results on Stabilization of the Paralytic Shoulder Report of the Research Committee of the American Orthopaedic Association, J Bone & Joint Surg 24: 699 1942.

Barr J S, and Ober F R: Leg Lengthening in Adults J Bone & Joint Surg 15 6 4, 1933
Barr, J S, and Record E E Arthrodesis of the Ankle for Correction of Foot Deformity S Clin North America 27 1281, 1947
Bick, Edgar M Source Book of Orthopaedics, ed. Baltimore 1948 Williams & Wilkins Co., p. 401
Bickel W H, and Moe J H: Translocation of the Peroneus Longus Tendon for Paralytic Calcaneus Deformity of the Foot Surg Gynec. Obst 78 627, 1944
Biesalski, K., and Mayer, L. Die Physiologische Sehnenverpflanzung Vol. XIV Berlin 1916, Julius Springer
Bisgard, J D., and Bisgard M E. Longitudinal Growth of Long Bones Arch Surg 31 568 1935
Blount Walter P: Personal communication 194
Blount W P: Blade Plate Internal Fixation for High Femoral Osteotomies J Bone & Joint Surg 25 319 1943.
Blount, W P: Osteoclasis for Supination Deformities in Children J Bone & Joint Surg 22 300 1940.
Bost, F C. Operative Lengthening of the Bones of the Lower Extremity Am. Acad. Orth. Surgeons Reconstruction Surgery of the Extremitie Ann. Arbor Mich., 1944 J W Edwards.
Brewster, A H: Countersinking the Astragalus in Paralytic Feet, New England J Med. 209 71, 1933
Brockway A Clinical Résum of Forty Six Leg Lengthening Operations, J Bone & Joint Surg. 17 969 1935
Brockway A., and Fowler S B.: Experience With 105 Leg Lengthening Operations Surg Gynec. Obst. 75 252, 1942
Calvé Jacques, and Galland Marcel A New Procedure for Compensatory Shortening of the Unaffected Femur in Cases of Considerable Asymmetry of the Lower Limbs, Fractures of the Femur Coxalgia etc., Am J Orthop Surg 16 211 1918.
Campbell Willis C. Surgery of Paralysis, Memphis Medical Monthly 33 481, 1913.
—: Subperiosteal Osteotomy of the Os Calcis for Pes Calcaneus Surg Gynec. Obst. 20 231 1915
— Operation for the Correction and Prevention of Paralytic Genu Recurvatum J A. M. A. 71 907 1918.
— An Operation for the Correction of Drop-Foot J Bone & Joint Surg 5 815 1923
— End Results of Operation for Correction of Drop-Foot, J A. M A. 85 1927, 1925
— The Stabilization of Paralytic Feet, Am. J Surg 3 62, 1927
— Bone-Block Operation for Drop-Foot Analysis of End Results, J Bone & Joint Surg 12 317, 1930
Campbell, Willis C., and Mitchell, Jos. I. Operative Treatment of Paralytic Genu Recurvatum, Ann. Surg. 96 1055 1932.
Carmack J C., and Hallock, Halford Tibiotarsal Arthrodesis After Astragalectomy A Report of Eight Cases, J Bone & Joint Surg 29 476 1947
Carrell W B Use of Fascia Lata in Knee-Joint Instability J Bone & Joint Surg 19 1018, 1937
Cleveland, Mather Operative Fusion of the Unstable or Flail Knee Due to Anterior Poliomyelitis. A Study of Late Results, J Bone & Joint Surg 14 525 1932.
Cole W H. Bony Fixation of the Foot in Infantile Paralysis; Subastragalar Arthrodesis J Bone & Joint Surg 12 289 1930
Cole W H.: The Treatment of Claw Foot, J Bone & Joint Surg 22 895 1940
Colonna, P C. Hamstring Transplantation for Quadriceps Paralysis, J Bone & Joint Surg. 5 472 1923
Compere E. L. Indications For and Against the Leg Lengthening Operation, J Bone & Joint Surg 18 692, 1936.
Crego C. H., Jr and Fischer F J: Transplantation of the Biceps Femoris for the Relief of Quadriceps Femoris Paralysis in Residual Poliomyelitis, J Bone & Joint Surg 13 515 1931
Crego C. H., Jr and McCarroll, H R.: Recurrent Deformities in Stabilized Paralytic Feet. A Report of 1100 Consecutive Stabilizations in Poliomyelitis, J Bone & Joint Surg. 20 609 1938
Davis, G G Wedge-Shaped Resection of the Foot for the Relief of Old Cases of Varus New York M J 56 370, 1892.
— The Treatment of Hollow Foot (Pes Cavus) Am. J Orthop. Surg 11 231 1913
Dickson, F D An Operation for Stabilizing Paralytic Hips A Preliminary Report, J Bone & Joint Surg 9 1 1927
— Fascial Transplants in Paralytic and Other Conditions J Bone & Joint Surg 19: 405 1937
Dickson, F D., and Diveley Rex L. Operation for Correction of Mild Claw Foot, the Result of Infantile Paralysis, J A. M A 87 1275 1926.

Digby, K. H.: The Measurement of Diaphyseal Growth in Proximal and Distal Directions, J Anat. 50 187 1916.
Dowman, Chas. E., and Hoke Michael The Treatment of Spastic Paralysis, Arch. Surg. 9 145, 1924.
Dunn, Naughton Stabilizing Operations in the Treatment of Paralytic Deformities of the Foot Proc. Roy Soc Med. (Sect. Orthop.) 15 15 1922.
—: Suggestions Based on Ten Years Experience of Arthrodesis of the Tarsus in the Treatment of Deformities of the Foot, Robert Jones Birthday Volume, London, 1928 Oxford University Press, p 395
—: The Surgery of Muscle and Tendon in Relation to Infantile Paralysis, Proc. Roy Soc. Med., Part I, 22 243 1928.
— Reconstructive Surgery in Paralytic Deformities of the Leg J Bone & Joint Surg 12 299 1930
Eaton G O: Results of Abdominal Stabilizations, South. M. J 34 443, 1941.
Evans, E. L. Astragalectomy Robert Jones Birthday Volume, London 1928 Oxford University Press, p. 375.
Fassett, F J An Inquiry as to the Practicability of Equalizing Unequal Legs by Operation, Am J Orthop. Surg 16 277 1918
Fitzgerald, F P., and Seddon H. J: Lambrinudi s Operation for Drop-Foot, Brit. J Surg 25 283, 1937
Forbes, A. Mackenzie Clawfoot and How to Relieve It Surg. Gynec. Obst. 16 81 1913.
Forbes, A. M. The Tensor Fasciae Femoris as a Cause of Deformity, J Bone & Joint Surg. 10 579, 1928.
Forrester Brown, M. F Tendon Transplantation for Clawing of the Great Toe, J Bone & Joint Surg. 20 57 1938.
Freiberg, A. H. Codivilla s Method of Lengthening the Lower Extremity Surg Gynec. Obst. 14 614, 1912.
Gallie W E. Tendon Fixation in Infantile Paralysis—A Review of One Hundred and Fifty Operations, Am J Orthop Surg 14 18 1916.
Gill, A. B. Fusion Operation on the Foot J A. M A. 89 1829 1927
— Operation for Correction of Paralytic Genu Recurvatum, J Bone & Joint Surg 13 49 1931
— An Operation to Make a Posterior Bone Block at the Ankle to Limit Foot Drop, J Bone & Joint Surg 15 166 1933.
Gill, G G., and Abbott, L. C.: Practical Method of Predicting the Growth of the Femur and Tibia in the Child, Arch. Surg 45 286 1942.
Green, W T., and Anderson Margaret: Experiences With Epiphyseal Arrest in Correcting Discrepancies in Length of the Lower Extremities in Infantile Paralysis A Method of Predicting the Effect, J Bone & Joint Surg 29 659 1947
Green, W T., Wyatt, G M., Anderson M.: Orthoroentgenography as a Method of Measuring the Bones of the Lower Extremity J Bone & Joint Surg 28: 60 1946.
Groves, E. W H. Some Contributions to the Reconstructive Surgery of the Hip, Brit. J Surg. 14 486, 1926-27
Haas, S. L.: Longitudinal Osteotomy J A. M A. 92 1656, 1929
—: The Treatment of Permanent Paralysis of the Deltoid Muscle J A. M. A. 104 99 1935.
Haas, S. L.: Retardation of Bone Growth by a Wire Loop, J Bone & Joint Surg 27: 25 1945.
Hallgrimsson, S.: Studies on Reconstructive and Stabilizing Operations on the Skeleton of the Foot, With Special Reference to Subastragalar Arthrodesis in Treatment of Foot Deformities Following Infantile Paralysis, Acta. chir Scandinav (supp. 78) 88 1 1943.
Hallgrimsson, S. Pes Cavus, Seine Behandlung und Einige Bemerkungen über seine Atiologie, Acta. orthop. Scandinav 10 73, 1939
Hallock, H. Surgical Stabilization of Dislocated Paralytic Hips; End Result Study, Surg Gynec. Obst. 75 742 194_
Hammond, G Elevation of the First Metatarsal Bone With Hallux Equinus, Surgery 13 240, 1943.
Hamsa W R. Panastragaloid Arthrodesis. A Study of End Results in Eighty five Cases, J Bone & Joint Surg 18 732, 1936.
Harmon, P H. Personal communication
Harmon, P H. Anterior Transplantation of the Posterior Deltoid for Shoulder Palsy and Dislocation in Poliomyelitis, Surg. Gynec. Obst. 84 117 1947
Harmon, P H., and Krigsten, W H. The Surgical Treatment of Unequal Leg Length, Surg Gynec. Obst. 71 482, 1940
Harris, R. I. Discussion of S. L. Haas paper Retardation of Bone Growth by a Wire Loop J Bone & Joint Surg 27 33 1945.
Harris, R. I., and McDonald, J L.: The Effect of Lumbar Sympathectomy Upon the Growth of Legs Paralyzed by Anterior Poliomyelitis, J Bone & Joint Surg 18 35 1936.

Hart V L. Arthrodesis of the Foot in Infantile Paralysis Surg Gynec. Obst. 64 794 193
Hart V L.: Lambrinudi Operation for Drop-Foot, J Bone & Joint Surg 22 937, 1940
Hatcher, C. H: Personal communication.
Hatt, R. N: (Quoted by Thompson, T C., personal communication.)
Henderson, M S.: Reconstructive Surgery in Paralytic Deformities of the Lower Leg J Bone & Joint Surg 11: 810, 1929
Henry, Arnold K An Operation for Slinging a Dropped Shoulder Brit. J Surg 15 95, 1927 28.
Heyman, C. H: The Operative Treatment of Claw Foot J Bone & Joint Surg 14 335 1932.
Heyman, C. H Personal communication 1946
Heyman, C. H: Operative Treatment of Paralytic Genu Recurvatum J Bone & Joint Surg 29 644 194
Hibbs, Russell A.: An Operation for "Claw Foot" J A M A. 73 1583, 1919
Hoke Michael: An Operation for Stabilizing Paralytic Feet J Orthop Surg 3 494, 1921
Howorth, M. B. Leg Shortening Operation for Equalizing Leg Length Arch. Surg. 44 543, 1942.
Hunkin S. J: An Improved Method for Treating Claw Foot Second Report of Progress in Orthopedic Surgery p 9
Inclan, Alberto: Artrorisis Posterior y Anterior del Tobillo, La Habana Cuba, 1939
Irwin C. E.: Subtrochanteric Osteotomy in Poliomyelitis, J A. M A 133 231 1947
Irwin, C. E.: Genu Recurvatum Following Poliomyelitis; Controlled Method of Operative Correction, J A. M A. 120 277 1942.
Irwin, C. E.: The Iliotibial Band and Its Role in Deformity in Poliomyelitis, Orthopedic Correspondence Club Letter March 6, 1947
Irwin, C. E.: Orthopedic Correspondence Club Letter, April 22 1946
Jones Sir Robert The Soldier s Foot and the Treatment of Common Deformities of the Foot. Part II: Claw Foot Brit. M J 1 749 1916.
King, B. B. Ankle Fusion for Correction of Paralytic Drop Foot and Calcaneus Deformities, Arch. Surg 40 90 1940.
Kleinberg S.: The Transplantation of the Hamstring Muscles for Quadriceps Palsy, Am. J Orthop Surg 15 512 1917
Kreuscher Philip H. The Substitution of the Erector Spinae for Paralyzed Gluteal Muscles, Surg Gynec. Obst. 40 593 1925
Lambrinudi C. New Operation on Drop-Foot, Brit. J Surg 15 193 1927
Lambrinudi C. L., and Stamm, T T: A Report of Work in the Orthopaedic Department of Guy s Hospital, Guy s Hosp Rep. 89: 184 1939
Lange, Fritz Die Technik des Orthopadischen Eingriffs, Ph J Erlacher Vienna 1928 Julius Springer p. 182.
— Epidemic Infantile Paralysis, Munich, 1930, J F Lehmanns Verlag, p. 240
— American and German Orthopedic Surgery J Bone & Joint Surg 13 479 1931
Lange, M. Die Bedeutung und Behandlung der Hüftbeugekontraktur nach Poliomyelitis, Ztschr f. orthop Chir 47 86, 1925
Lapidus, Paul W "Dorsal Bunion": Its Mechanics and Operative Correction J Bone & Joint Surg 22 627 1940
Legg, Arthur T Transplantation of Tensor Fasciae Femoris in Cases of Weakened Gluteus Medius, J A. M A. 80 242, 1923.
—: Tensor Fasciae Femoris Transplantation in Cases of Weakened Gluteus Medius, New England J Med. 209: 61 1933
Liebolt, F L. Pantalar Arthrodesis in Poliomyelitis, Surgery 6 31 1939
Lowman, C. L. Orthopedic Correspondence Club Letter April 6, 1941
Lowman C. L. Orthopedic Correspondence Club Letter April 22 1946
Lowman, C. L. Plastic Repair for Paralysis of Abdominal Musculature, New England J Med. 205 1187 1931.
—: The Relation of the Abdominal Muscles to Paralytic Scoliosis, J Bone & Joint Surg 14 763 1932.
MacAusland, W R. Poliomyelitis, Philadelphia 1927 Lea & Febiger
—: Subastragalar Arthrodesis, Arch. Surg 18 024 1929
MacAusland, W R., and MacAusland A R.: Astragalectomy (the Whitman Operation) in Paralytic Deformities of the Foot, Ann. Surg 80 861 1924
McCarroll H. R. Foot Deformities Resulting From Irreparable Nerve Lesions Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor Mich., 1944, J W Edwards.
McDonald, J L.: Discussion of S. L. Haas Paper Retardation of Bone Growth by a Wire Loop J Bone & Joint Surg 27 36 1945
Marshall, H. W., and Osgood, R. B.: Late Results of Operations for Correction of Foot Deformities Resulting from Poliomyelitis, Boston M. & S. J 173 375 1915
Mayer Leo The Physiological Method of Tendon Transplantation, Surg Gynec. Obst. 22 182, 1916.

— The Physiological Method of Tendon Transplantation Surg Gynec. Obst. 22 298, 1916
— The Physiological Method of Tendon Transplantation, Surg Gynec. Obst. 22: 472, 1916.
— The Surgery of Tendons, Abt s Pediatrics, Philadelphia, 1924 Vol. 5 W B Saunders Co., p 112.
—: Transplantation of the Trapezius for Paralysis of the Abductors of the Arm, J Bone & Joint Surg 9 412, 1927
—: The Operative Treatment of Paralytic Deformities of the Foot, Am. J Surg. 7 80, 1929
— An Operation for the Cure of Paralytic Genu Recurvatum, J Bone & Joint Surg. 12: 845, 1930.
— Fixed Paralytic Obliquity of the Pelvis, J Bone & Joint Surg 13 1 1931
—: Surgery of Tendons, Cyclopedia of Medicine, Vol. XII, Philadelphia, 1934 F A. Davis Co p. 1
— Further Studies of Fixed Paralytic Pelvic Obliquity J Bone & Joint Surg. 18 87 1936.
Mayer L. The Significance of the Iliocostal Fascial Graft in the Treatment of Paralytic Deformities of the Trunk, J Bone & Joint Surg 26 257 1944.
Mayer L. Tendons, Ganglia Muscles, Fascia, Dean Lewis Practice of Surgery, Vol. III, Hagerstown, MD., 1942, W F Prior Co., Inc.
Miller, O L. Paralytic Knee Fusions, South. M J 20 782, 1927
— Drop Foot from Infantile Paralysis and Cord Injuries Corrected by Campbell Bone Block Operation, South. Surgeon 1 323, 1933.
— Surgical Management of Pes Calcaneus, J Bone & Joint Surg 18 169 1936.
Miltner L. J Stabilization of the Foot; a Study of Late Results, J Bone & Joint Surg. 13 502, 1931
Mitchell, Jos. L: The Residual Paralysis and Deformity of Anterior Poliomyelitis, J Bone & Joint Surg 7 619 1925.
Moore, B H. A Bone Lengthening Apparatus, J Bone & Joint Surg 13 170 1931
Moore, B. H.: A Critical Appraisal of the Leg Lengthening Operation, Am. J Surg 52 415 1941
Moore R. D. Supracondylar Shortening of the Femur for Leg Length Inequality, Surg Gynec. Obst. 84 1087 1947
Nové-Josserand, G: ' Artrorise of the Foot, J Bone & Joint Surg. 10 261 1928.
Ober Frank R.: An Operation for Relief of Paralysis of the Gluteus Maximus Muscle, J A. M A. 88 1063, 1927
— An Operation to Relieve Paralysis of the Deltoid Muscle J A. M A. 99 2182, 1932.
— Tendon Transplantation in the Lower Extremity New England J Med. 209 52, 1933.
Ober F R. Transplantation to Improve the Function of the Shoulder Joint and Extensor Function of the Elbow joint, Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann. Arbor Mich., 1944, J W Edwards.
Ober F R., and Barr J S. Brachioradialis Muscle Transposition for Triceps Weakness, Surg Gynec. Obst. 67 105 1938
O'Donoghue D H.: Personal communication, 1947
O'Donoghue D H. Controlled Rotation Osteotomy of the Tibia, South. M. J 33. 1145, 1940
O'Donoghue D H., and Stauffer R. An Improved Operative Method for Obtaining Bony Fusion of the Great Toe, Surg Gynec. Obst. 76: 498, 1943.
Painter C. F: A Case of Transplantation of the Biceps Femoris Tendon, Boston M. & S. J 147: 381, 1902
Palagi, P., and Giuntini, L. Modern Trends of Orthopedic Therapy of Sequels of Infantile Paralysis (Paralysis of Trunk, Extremities or Joints, or Other Deformities) Arch. di ortop 48 305 1932.
Peabody Charles W: Tendon Transposition; an End Result Study J Bone & Joint Surg 20 193 1938.
Peabody C. W Orthopedic Correspondence Club Letter June 8 1942.
Phalen, G S., and Chatterton C. C. Equalizing the Lower Extremities, A Clinical Consideration of Leg Lengthening Versus Leg Shortening, Surgery 12 768 1942.
Phemister D B.: Operative Arrestment of Longitudinal Growth of Bones, in the Treatment of Deformities, J Bone & Joint Surg. 15 1 1933.
Putti, V: The Operative Lengthening of the Femur J A. M. A. 77 934, 1921.
—: Operative Lengthening of the Femur Surg Gynec. Obst 58: 318 1934.
Regan, J M., and Chatterton, C. C.: Deformities Following Surgical Epiphyseal Arrest, J Bone & Joint Surg 28 265, 1946.
Robbins, Albert L Inequality of Leg Lengths, Mimeographed, Hosp. for Special Surgery Feb. 14 1947
Ryerson, E. W Osteotomy for Flexion Deformity at the Hip Due to Anterior Poliomyelitis, J A. M. A. 101 1876 1933.
Ryerson, E. W Arthrodesing Operations on the Feet, J Bone & Joint Surg 5 453 1923.

Saunders, J T: Etiology and Treatment of Clawfoot, Report of Results in 102 Feet Treated by Anterior Tarsal Resection, Arch. Surg 30 179, 1935
Scaglietti, O: Ricupero funzionale di un arto poliomielitico Boll e mem Soc Emiliano-Romagnola di chir., Vol. I, Nos. IV V 1935
Scherb, R. Transplantation of Tendons in Paralysis in Poliomyelitis Biologic and Technical Study, Ztschr f orthop. Chir 61 303 1934
Schnepp Kenneth H.: Hammer Toe and Claw Foot Am. J Surg 36 351, 1937
Schwartz R P Arthrodesis of Subtalus and Midtarsal Joints of the Foot, Historical Review Preoperative Determinations, and Operative Procedure Surgery 20 619 1946.
Sherman, H M: The Operative Treatment of Pes Cavus, Am J Orthop Surg. 2 374, 1904-05
Smith, Alan DeF: Correction of Deformities of the Lower Extremity in Poliomyelitis S. Clin North America 17 227 1937
Smith, A DeF., and von Lackum H. L. End Results of Operation for Claw Foot, J A. M A. 84 409 1925.
Speed, J S: End Results in Transference of the Crest of the Ilium for Flexion Contracture of the Hip J Bone & Joint Surg 10 202, 1928
Spitzy H., and Lange F: Orthopädie im Kindesalter, Vol 8 v Pfaundler & Schlossmann s Handbuch der Kinderheilk., Leipzig 1930
Steindler Arthur Nutrition and Vitality of the Tendon in Tendon Transplantation, Am. J Orthop. Surg 16 63 1918.
Steindler A.: Tendon Transplantation in the Upper Extremity, Am. J Surg 44 260 1939
Steindler A. The Treatment of the Flail Ankle Pan Astragaloid Arthrodesis, J Bone & Joint Surg 5 284 1923.
Steindler A Muscle and Tendon Transplantation at the Elbow Am. Acad. Orth. Surgeons Reconstruction Surgery of the Extremities, Ann Arbor Mich., 1944, J W Edwards.
— Report on 48 Cases of Tendon Transplantation of the Foot. Physiological Method, J Orthop. Surg. 1: 187 1919
—: Operative Treatment of Paralytic Conditions of the Upper Extremity, J Orthop. Surg 1 608 1919
— Stripping of the Os Calcis, J Orthop Surg 2 8 1920
— Reconstructive Surgery of the Upper Extremity New York, 1923 D Appleton & Co., p. 36.
— Operative Orthopedics, New York, 1925 D Appleton & Co., p. 80
Straub L. R., Thompson, T C., and Wilson, P D: The Results of Epiphyseodesis and Femoral Shortening in Relation to Equalization of Limb Length, J Bone & Joint Surg 27 254 1945.
Thompson, T C. Astragalectomy and the Treatment of Calcaneovalgus J Bone & Joint Surg 21 627 1939
Thompson, T C. Orthopedic Measures for Use in Irreparable Nerve Injury J Internat. Coll. Surgeons 9 110 1946.
Todd, T W Atlas of Skeletal Maturation St. Louis, 1937 The C. V Mosby Company
Toupet R.: Torsion Arthrodesis for Drop-Foot, J de Chir 16 268 1920.
Tubby A. H.: Deformities and Diseases of Bones and Joints, Vol. II, London 1912 The Macmillan Co., Ltd., p 728
Von Baeyer H. Translokation der Sehnen Zentralbl. f Chir 58: 3140 1931
Von Baeyer H.: Translokation von Sehnen Ztschr f Orthop Chir 56: 532, 1932.
Wagner L. C Modified Bone Block (Campbell) of Ankle for Paralytic Drop-Foot J Bone & Joint Surg 13 142, 1931.
— The Operative Correction of Extreme Flexion Contraction of the Great Toe, J Bone & Joint Surg. 16 914 1934
Wagner L. C., and Rizzo P C. Stabilization of the Hip by Transplantation of the Anterior Thigh Muscles, J Bone & Joint Surg 18 180 1936.
Watkins, Jas. T: Concerning the Operative Treatment of Claw Foot, Am. J Orthop. Surg 10 230 1912 13.
Weber Luis A. El Tratamiento de las Secuelas Poliomieliticas del Pie Sebastián de Amorrortu Buenos Aires, 1930
West Dr Francis E. Personal communication.
White, J Warren Femoral Shortening for Equalization of Leg Length J Bone & Joint Surg 17: 597 1935.
White J W Personal communication, 1946 and 1947
White J W: A Simplified Method for Tibial Lengthening J Bone & Joint Surg 12 90 1930
White, J W Overlapping Procedure for Shortening Bone Defects Course Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor Mich., 1944, J W Edwards.
White J W: Disorganization of the Foot, Am. Acad. Orth. Surgeons, Reconstruction Surgery of the Extremities, Ann Arbor, Mich., 1944 J W Edwards.

White J W A Practical Graphic Method of Recording Leg Length Discrepancies, South. M. J 33 940 1940
White, J W The Present Status of the Leg Length Discrepancy Problem, Ann. Surg. 125 602, 1947
White, J W, and Stubbins, S. G., Jr Growth Arrest for Equalizing Leg Length, J A. M. A. 126 1146, 1944.
White, J W., and Warner, W P., Jr: Experiences with Metaphyseal Growth Arrests, South. M J 31 411 1938
Whitman Armitage: The Modified Loop Operation for the Relief of Paralytic Equinovalgus, J Bone & Joint Surg 13 122 1931
Whitman, Royal Astragalectomy Orthopedic Surgery ed. 6 Philadelphia, 1919 Lea & Febiger p 808.
— Orthopedic Surgery, ed. 9 Philadelphia, 1930 Lea & Febiger, p. 912.
— The Operative Treatment of Paralytic Talipes of the Calcaneus Type, Am. J M. Sc. 122 593 1901
Williamson G A., Moe J H., and Basom, W C. Results of the Lowman Operation for Paralysis of the Abdominal Muscles, Minnesota Med. 25 117, 1942.
Wilson P D., and Thompson, T C.: A Clinical Consideration of the Methods of Equalizing Leg Length, Ann. Surg 110 992 1939
Yount C. C. The Role of the Tensor Fasciae Femoris in Certain Deformities of the Lower Extremity, J Bone & Joint Surg 8 171 1926
Yount, C. C. An Operation to Improve Function in Quadriceps Paralysis, J Bone & Joint Surg 20 314 1938.

CHAPTER XXIII

MISCELLANEOUS AFFECTIONS OF THE NERVOUS SYSTEM

CEREBRAL PALSY*

Cerebral palsy may be properly defined as any type of disturbance of muscular function which arises from an intracranial lesion of the central nervous system. In this classification from a standpoint of treatment, though not properly a form of cerebral palsy may be included that type of palsy wherein the disturbance is in the proximal portion of the cervical cord just below the decussation of the pyramids Though in the past the various types of cerebral palsy have been grouped under the general term "cerebral spastic paralysis" this term is not suitable for the entire group, true cerebral spastic paralysis comprises only one of the five types of cerebral palsy, the others being the athetoid, ataxic tremor and rigidity types. The incidence of each of these is approximately as follows cerebral spastic paralysis 30 per cent, athetosis 30 per cent ataxia 10 per cent, tremor 5 per cent, rigidity 20 per cent, and mixed cases 5 per cent

Heretofore the approach to the treatment of cerebral palsy has been to a large extent, surgical in nature. This section, however will deal with the comprehensive treatment indicated in the light of present knowledge and will consider the nonoperative as well as operative measures. Surgery is only one part of a broad plan of treatment which aims at making the patient not only physically independent, but also socially competent and acceptable. Although frequently required to overcome an obstruction to rehabilitative progress, surgical treatment is not in any way to be considered a substitute for physical rehabilitative measures The value of surgical treatment, therefore should be measured not only by its contribution to the correction of a local physical disturbance but also by its contribution toward the broad rehabilitation of the patient.

General Discussion

The intracranial lesions responsible for cerebral palsy may be divided into three general groups (1) those of the motor cortex, (2) those of the base of the brain and (3) those of the cerebellum. The muscular manifestations will, of course vary according to the location of the intracranial lesion though it is not always possible from a clinical standpoint, to localize the lesion with absolute accuracy In general however lesions of the motor cortex result in spasticity and flaccidity lesions at the base of the brain give rise to athetosis tremor and, in some instances rigidity and lesions of the cerebellum produce ataxia and incoordination. Rarely diffuse lesions which affect several parts of the brain may be evidenced by combinations of these motor manifestations these, however are usually so extensive as to be incompatible with life. Thus on the whole the clinical picture in the individual case is clearly representative of one of the five types of cerebral palsy

*The author of this section was associated with Dr Winthrop M. Phelps for one year and acknowledges him as the major source of this material.

Phelps has shown by statistical studies that seven children per 100 000 of *population are born with cerebral palsy each year* This is constant, regardless of the locality or financial status of the individual The mortality rate during infancy is approximately one seventh of the total number thus, six patients with cerebral palsy each year per 100 000 of population will require continued medical supervision. Of these six two are definitely feebleminded and require institutional treatment, and the four with normal mentality may be grouped as follows one is severe and is homebound two are of moderate degree and may be definitely improved and one is so mild that little if any treatment is necessary It is evident that the two principal problems are (1) development of institutional care for the feebleminded and those who are so severely handicapped physically that rehabilitation cannot be carried out despite normal mental ability and (2) development of training centers for the moderately handicapped of normal mentality who may be rehabilitated to a worth while degree. Consideration of the first problem is, of course, not within the scope of this section.

Etiology

Although many observers believe the chief cause of cerebral palsy is injury to the brain at the time of birth, according to Phelps, poor obstetric supervision accounts for crippling in less than 3 per cent of the cases. Not infrequently prenatal developmental or congenital brain defects are responsible especially in the ataxias and certain of the athetoids. Cerebral palsy is fairly common in children of mothers who have had rubella (German measles) or other virus disease during the first trimester of pregnancy Usually other congenital defects, such as congenital cataracts congenital deafness and septal cardiac defects are also present. In the presence of a symmetry of clinical manifestations such as bilateral and equal involvement of the arms and legs hemorrhage probably is not the etiologic factor since areas of *hemorrhage tend to be irregular In some cases congenital athetosis may* account for the difficult birth of the child rather than the trauma of the difficult birth producing the athetosis.

Intracranial birth hemorrhage is usually responsible for spastic paraplegia in prematurely delivered children In these the delicate and incompletely developed cerebral vessels are more readily ruptured during the rapid delivery by the sudden drop from the high intrauterine pressure to atmospheric pressure This sudden pressure change usually produces a hemorrhage in the vertex of the brain beneath the anterior fontanel with damage to the leg areas of the motor cortex and consequent spastic paraplegia.

In general birth injuries may be divided into two groups those of mechanical origin and those induced by prolonged anoxia *Mechanical injury* may be caused by fracture of the skull and cortical hemorrhage incident to incorrectly applied forceps or by failure to use forceps in protracted and difficult labors. Excessive traction on the neck may also give rise to intracranial hemorrhage from a ruptured vein of Galen. Anoxia may be produced by a number of factors including injudicious use of analgesics and anesthetics in the second stage of labor passive cerebral congestion from wrapping of the umbilical cord around the neck of the fetus, or from difficult resuscitation of the infant. A history of prolonged periods of apnea or cyanosis is frequently obtained in relation to cerebral palsy

More recently the severe jaundice which may be associated with erythro*blastosis fetalis and Rh factor disturbances has* been found to lead to damage

of the basal ganglia and is probably the primary factor in a far larger number of the athetoids than has previously been realized

The most common postnatal cause of cerebral palsy is encephalitis In the infectious encephalitides, the course may often be progressive in encephalitis following measles pertussis pneumonia, and other infective diseases, the palsy is more likely to be static and improvement may be expected with treatment. Postnatal convulsive seizures likewise play a prominent role particularly those which appear during the first few weeks of life In many cases convulsions at this age arise from hemorrhage or congenital defect, though in others the convulsion itself may be responsible for the hemorrhage Convulsions may develop later in childhood in patients with asymmetrical cerebral palsy and a complicating mixed dominance If the convulsion leads to hemorrhage spasticity and flaccidity will be superimposed upon the original palsy

Description of Types

Since the details of treatment vary in the different types of cerebral palsy a distinction between these types is essential

Lesions of the Cerebral Cortex.—Damage to the cerebral cortex produces either muscle spasticity or flaccidity or both depending upon the location of the damage True spasticity arises from involvement of the premotor area (area 6 of the Brodmann classification) while involvement of the motor area proper (area 4 of the Brodmann classification) leads to muscle flaccidity which is somewhat similar to lower motor neuron flaccidity Most hemorrhages in the motor area produce an admixture of spasticity and flaccidity of muscle. Thus, the usually accepted concept that cerebral cortical damage results in spasticity alone is not correct in every case. For this reason, a careful examination must be made to determine which muscles are spastic which are flaccid which are normal and which are normal but weak from prolonged stretching and disuse. In spastic paralysis, there is probably no absolute paralysis in the presence of flaccidity from an area 4 lesion, contractions of the affected muscles may be obtained by "confusion" on forceful resisted contraction of other muscles in the body At times a muscle may be cerebral flaccid for one function and not for another as for example the flexor carpi ulnaris may be cerebral flaccid for wrist flexion yet may function normally in conjunction with the extensor carpi radialis longus when acting as an abductor of the wrist Confusions are usually constant for a given muscle, e g in the presence of cerebral flaccid dorsiflexors of the foot, contraction may usually be obtained by resisted flexion of the hip

The hemorrhage may be located toward the vertex of the brain, thus affecting chiefly the legs or it may extend lower on the cortex and also affect the arms If the hemorrhage is in only one side of the brain hemiplegia of the contralateral side of the body will follow If in the dominant side of the brain the hemorrhage may involve the speech area. It should be remembered that the area of hemorrhage is usually irregular and results in an irregular distribution of muscle dysfunction thus in an involved arm or leg there may be a mixture of spastic muscles, normal muscles, and flaccid muscles These should be accurately charted not only to form a basis for treatment, but also to provide information in regard to contractures and deformities which may develop unless preventive measures are instituted.

True spasticity gives rise to hypercontractility of muscle on stretching Thus in the presence of a spastic quadriceps an attempt to flex the knee

actively is followed immediately by contraction of the quadriceps, which blocks the knee flexion. The intrinsic contractile function of the spastic muscle itself is not impaired. The deep tendon reflexes of the spastic muscles are hyperactive and, in many cases clonus may be present, this is evidence of an exaggeration of the stretch reflex. Rarely the damage is limited essentially to area 4, wherein there is an almost complete flaccidity instead of spasticity of the involved extremities.

Lesions of the Base of the Brain.—Damage of the basal ganglia is followed by the release of involuntary impulses which are reflected in many different types of involuntary motion Such movements may be rapid or slow constant or intermittent, or they may appear only with effort. The various types of athetosis are designated by descriptive terms such as tension, non tension, tremor flail and dystonic. The athetosis may involve any or all of the extremities as well as the muscles supplied by the cranial nerves. When the facial muscles and the muscles of speech are involved, the constant grimacing and twitching often leads to an incorrect diagnosis of mental deficiency If the damage is limited to the base of the brain, the mentality is not necessarily affected and careful study must be made in order that one may not be misled by distortion or lack of speech.

Muscle spasticity is not produced by basilar damage or malformation, though many athetoids exhibit evidence of tension which has been secondarily developed to control the involuntary motions these are called tension athetoids.' This tension is differentiated from spasticity by the absence of the stretch reflex. In the spastic, the stretch reflex is consistently present, while in the tension athetoid, the tension can be shaken loose by repeated rapid passive flexion and extension (shaking) of the involved joints of the extremity

Tremor is rarely of congenital origin usually it follows postnatal encephalitis and responds to the medication used in other postencephalitic tremors and to physical rehabilitative measures.

Lesions of the Cerebellum.—Lesions of the cerebellum produce ataxia and a disturbance or loss of kinesthetic sense Ataxia is usually characterized by a loss of postural sense and balance. The muscles do not have the fundamental synchronous contraction of prime mover and relaxation of antagonist in response to changes of position in relation to gravity The muscles of speech, the trunk and the arms as well as the legs are involved. These children usually learn to walk late and because of this delay may have some shortening of the tendo achillis. The speech may be affected by ataxia of the tongue. Nystagmus is generally associated and dizziness and nausea may be experienced on attempts at close fixation of the eyes for reading The condition is usually congenital in origin, though occasionally it may be induced by birth hemorrhage. The typical ataxic will improve spontaneously to a relatively greater degree than patients with other types of cerebral palsy, and is capable of learning voluntary balance control through re-education of the motor pathways Frequently such patients manifest incomplete fixation of handedness and evidences of mixed dominance as a result of the rather symmetrical loss of kinesthetic sense in the arms.

Rigidity.—This type of cerebral palsy may arise from diffuse damage to the brain following prolonged anoxia after birth, or from multiple petechial hemorrhages of the brain incident to venous stasis, which in turn is caused by strangulation by the cord around the neck at birth. Rigidity is characterized

by a loss of elasticity of muscle and a "lead pipe" response to passive flexion or extension of a joint. A definite sense of stiffness is elicited on attempts to stretch the muscles though no true stretch reflex is found The reflexes may be variable but are not usually hyperactive unless the muscle is in a state of active contraction at the time of eliciting the reflex so that the reflex is reinforced The rigidities may be constant or intermittent. In the latter periods of muscular rigidity alternate with periods of relaxation Because of the diffuse brain involvement the incidence of mental impairment in this group is relatively high particularly in the constant rigidities The outlook both as to spontaneous improvement as well as to improvement from training and re-education is more promising in those with intermittent rigidity

Although generally diffuse the lesion will, at times result in a clinical picture similar in some respects to that of the postencephalitic rigidities and to the rigidity of Parkinsonism.

Mental Status.—In considering a cerebral palsied child for treatment one must take into consideration his mental status and the effect of the palsy upon his retarded development. In the past, the association of mental deficiency with cerebral palsy was considered the rule the vast majority of these patients were therefore promptly dismissed without treatment. It is now known that the mentality of 70 per cent of the patients is within normal limits. Unless gross defects in mentality can be proved the child with cerebral palsy should not be deprived of appropriate therapy merely because his motor and verbal responses are abnormal

The determination of the state of mentality is difficult since the standard mental tests are based upon motor activity and verbal response and are by no means infallible A combination of several tests should be employed and every part of the body must be taken into consideration. Repetition of these tests at intervals the child having meanwhile received adequate and concentrated treatment will yield much more accurate information regarding the child s mentality Preferably the tests should be made at intervals of one year Mistakes may be made in a single mental evaluation and harm may be done by attempts to classify the borderline cases from tests of motor activity alone Phelps has pointed out the difficulty which the psychologist encounters in being indifferent to the appearance and speech of the patient whose intelligence he is testing It should be considered that these children have five *extremities* two arms two legs and the speech mechanism including the face. Involuntary motion of the muscles of the face and speech *should no* more be considered evidence of feeblemindedness than paralysis of an arm.

The number of those who are mentally normal but retarded as a result of the physical handicap is larger than the number of the actually feebleminded. The physiologic age of the body usually fails to keep pace with the chronologic age, and only by thorough study may all the developmental abnormalities be determined and their significance evaluated. One must sum up the emotional age the social age and the mental age and then make allowance for the patient s handicaps. The physician must remember that many of these patients will improve mentally as their physical handicap improves through training and treatment. Much of the backwardness can be accounted for by the lack of development which proceeds by grasp and touch in every child As Carlson has said A sound mind behind a crippled body will also become crippled unless we provide that mind with adequate channels for the

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otions are first acquired by training These functions are taught by muscle lucation by having the child repeat a fundamental motion, making the most the intact portion of the brain and adapting or substituting the function some other part of the brain for that of the part which has been damaged the older child with spasticity, voluntary exercises to strengthen the weak ntagonists are of definite value Passive exercises should be avoided when ssible, when used, the stretch reflex should be excited as little as possible. ubstitution and adaptation of the intact cortex is encouraged early by simple onditioning exercises the skilled motions of necessity being postponed until ter in the course of treatment. Motions should be carried out through ac urate ranges at properly regulated speeds. As training progresses coordina on as manifested by rhythm increased speed and accuracy is sought. Per stent training of voluntary joint motion through the stretch reflex is sought nd after a period of time the ability to perform a given motion without inter rence by the stretch reflex will materially increase

Because of the fundamental muscle imbalance incident to spastic muscles ormal muscles, weak muscles and apparently paralyzed muscles in a given xtremity contractures are prone to develop in the patient with spasticity areful attention should be maintained to prevent the development of these ontractures. The most common is the equinus deformity in addition to re eated stretching and maintenance of a full range of dorsiflexion of the ankle ith the knee and hip in extension provision must be made to prevent an quinus position of the foot and ankle at night A single caliper night brace ith a round bar a right angle stop and a T strap is the most efficient form of ight brace If the Achilles tendon is contracted the bar of the night brace ay be bent at intervals thus forcing the foot and ankle in dorsiflexion and gradually stretching out the contracture These braces must be worn con tantly at night until growth of the long bones is complete usually at the age f 14 or 15 years

Braces are also utilized as supports to enable the patient to stand and hereby gain muscle strength and balance sense Use of the arm is also en ouraged by the upright position and the patient benefits immeasurably by eing in a position from which he can better see what goes on in the world bout him

In *athetosis* the underlying ability of the patient to move a muscle nor mally is unimpaired though the involuntary motion is superimposed. Repeti ercises will not increase the ability of an athetoid to perform a given e perfectly since the athetoid movements are never exactly the same er time Hence repetition is not successful as a treatment of athetosis. l postures result from an attempt by the body to attain a certain by the use of any available muscles. Following interference with pt by braces or surgical stabilization other muscles of the extremity ought into play to accomplish this same distortion or one of similar Likewise another characteristic of athetosis is the patient s o attempt to overcome athetoid motion by voluntary tension of the mity which eventually becomes habitual This produces a rigid art which suggests spasticity and is at times differentiated from y with difficulty

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reception and expression of ideas.' When the hand is difficult to control, an appreciable delay in the mental development of the child may result. Despite the irreparable brain damage in the child with cerebral palsy the developing nervous system has tremendous powers of adaptation and substitution of intact portions for the damaged portions. The cortical control developed by these children is analogous to the automatic playing of scales on a piano from repeated practice

The Training Program

The training program for the cerebral palsied child should be directed toward the development of the following (1) Speech, (2) Self help (3) Locomotion (4) Special education.

One must take into consideration the handicaps of the individual child and alter accordingly the sequence and final goals to be reached. Cerebral palsy requires a therapeutic program covering many years, and if the child's mind is seriously defective the program should not be elaborate The severity of the physical handicap is no index of the degree of mental impairment or of the child's fundamental ability to profit by training The first consideration is usually the institution of a plan which will make the child more independent at home and promote social and emotional adaptation. If the patient is physically and mentally capable measures to promote economic independence should be instituted later An adequate program will include psychological and speech training as well as special education and medical treatment.

The normal child is endowed from birth with a certain pattern of development. He sits at six months of age and walks at one year of age thus, there is an optimal time for the acquisition of each activity This pattern should be followed as closely as possible in the training of a child with cerebral palsy A child of eighteen months is taught to walk more easily than the five year old who is taller heavier and in whom the urge for walking has been discarded. It is obvious therefore, that treatment should be instituted as soon as the diagnosis is made

Spasticity is characterized by the presence of the stretch reflex A spastic muscle, when stretched will contract to the maximum degree as a result of the exaggerated stretch reflex. The damage to the brain is in the motor cortex or the pyramidal system and many of the primary fundamental motions are acquired by the spastic child only by repetitive training of these fundamental motions, just as a normal person acquires a skill such as typing by repetition. In the infant passive stretching of a spastic muscle does not elicit the resistance found at a later age and if treatment is begun early spastic contractures may be largely prevented Gross motions and the value of relaxation may be learned at an early age Early treatment eliminates the necessity of later unlearning bad habits acquired in infancy During infancy the spastic child does not learn automatically the fundamental motions such as reciprocal motion of the legs, normal reach and grasp of the arms, as spasticity prevents these motions. The normal infant soon learns to kick first with one leg and then the other to observe his hands and to reach and grasp nearby objects. He develops the ability to place objects in his mouth and to take them out again with great facility This is all training toward proper arm use On the other hand the spastic child is deprived of this practice and thus cannot learn the more complicated arm and leg functions until the rudimentary voluntary

motions are first acquired by training These functions are taught by muscle education by having the child repeat a fundamental motion, making the most of the intact portion of the brain and adapting or substituting the function of some other part of the brain for that of the part which has been damaged In the older child with spasticity, voluntary exercises to strengthen the weak antagonists are of definite value Passive exercises should be avoided when possible, when used the stretch reflex should be excited as little as possible Substitution and adaptation of the intact cortex is encouraged early by simple conditioning exercises, the skilled motions of necessity being postponed until later in the course of treatment. Motions should be carried out through accurate ranges at properly regulated speeds As training progresses coordination as manifested by rhythm increased speed and accuracy is sought. Persistent training of voluntary joint motion through the stretch reflex is sought, and after a period of time the ability to perform a given motion without interference by the stretch reflex will materially increase

Because of the fundamental muscle imbalance incident to spastic muscles, normal muscles, weak muscles and apparently paralyzed muscles in a given extremity contractures are prone to develop in the patient with spasticity Careful attention should be maintained to prevent the development of these contractures The most common is the equinus deformity in addition to repeated stretching and maintenance of a full range of dorsiflexion of the ankle with the knee and hip in extension provision must be made to prevent an equinus position of the foot and ankle at night. A single caliper night brace with a round bar a right-angle stop and a T-strap is the most efficient form of night brace If the Achilles tendon is contracted the bar of the night brace may be bent at intervals, thus forcing the foot and ankle in dorsiflexion and gradually stretching out the contracture These braces must be worn constantly at night until growth of the long bones is complete usually at the age of 14 or 15 years.

Braces are also utilized as supports to enable the patient to stand and thereby gain muscle strength and balance sense Use of the arm is also encouraged by the upright position and the patient benefits immeasurably by being in a position from which he can better see what goes on in the world about him.

In *athetosis* the underlying ability of the patient to move a muscle normally is unimpaired though the involuntary motion is superimposed. Repetitive exercises will not increase the ability of an athetoid to perform a given act more perfectly since the athetoid movements are never exactly the same time after time Hence repetition is not successful as a treatment of athetosis. Athetoid postures result from an attempt by the body to attain a certain position by the use of any available muscles Following interference with this attempt by braces or surgical stabilization, other muscles of the extremity will be brought into play to accomplish this same distortion or one of similar character Likewise another characteristic of athetosis is the patient's tendency to attempt to overcome athetoid motion by voluntary tension of the whole extremity which eventually becomes habitual This produces a rigidity of the part which suggests spasticity and is at times differentiated from true spasticity with difficulty

In athetosis the treatment is designed to overcome involuntary motion. These motions disappear on relaxation and in sleep The patient is trained in voluntary and conscious relaxation by the Jacobson technic *After the*

involuntary motions are abolished purposeful and coordinated motions are then trained in from the relaxed position. Usually training should be begun at the proximal portion of the athetoid extremity A hand which is capable of good function cannot be used efficiently if function of the shoulder is so poor that the hand cannot be placed in a useful position.

The athetoid, because of his constant movements, is not particularly prone to develop contractures. Postural contractures may occasionally develop because of improper posture associated with delayed walking and standing and because of the constant sitting or lying position of the patient. These cases require the use of corrective braces. Aside from these the only real purpose of bracing in the training and treatment of athetosis is the control of the involuntary motions. By prolonged and constant use of braces which control athetoid motions of the lower extremities the hips, and the back, a pattern of motion can be trained in and the simple straight forward walking motion permitted by the brace will be copied for increasingly long periods of time after the braces are removed Unfortunately such braces cannot be constructed for the upper extremity

For the *ataxic* the treatment program should include improvement of muscle tone development of sitting and standing balance, improvement of gait, and eye-to-hand skill training for the arms. Muscle tone is improved by physical therapy and medical measures, the latter including the administration of an abundance of vitamin B_6 and E. To improve the gait, it is chiefly necessary to narrow the base improve foot placement and to increase the patient's sense of security Short caliper braces which prevent ankle extension beyond a right angle are frequently required, and the shoes should have rubber soles and heels to give the patient a better "grip" on the floor in walking. Foot placement training will frequently do much to improve the appearance of the gait. Eye-to-hand skill is usually developed with difficulty because of the characteristic difficulty of fixation upon close objects Surgery is practically never indicated.

The *rigidities* present a therapeutic problem similar to that of spasticity though neurectomies, stabilizations and tendon surgery are rarely employed because of the underlying intracranial pathology Surgery is indicated in a few cases only for correction of a major contracture or deformity

SURGERY IN CEREBRAL PALSY

Surgery has a definite place in the treatment of cerebral palsy of the spastic type though in no other It should never be employed, however until after a thorough evaluation of the patient has been made from all standpoints and after a period of adequate and conscientious conservative therapy has been carried out. Without conservative therapy one cannot determine just which phases of the patient's rehabilitation can be cared for without surgery and which portions of the palsy require surgery because of failure to accomplish rehabilitation of that part by conservative means. As Steindler has said, "Operative interference is only an episode" in the treatment of cerebral palsy The operative treatment is without exception contingent upon the failure, either proved or occasionally justifiably expected of the conservative treatment.

It should be recognized that spastic contractures arise from innervational overload or imbalance and are far more amenable to passive correction than contractures of other types This is because the resistance of the spastic

muscle against stretch is gradually diminished rather than increased as the corrective measure proceeds Thus many spastic contractures which at the outset appear impossible of conservative correction are corrected with relative ease without resort to surgery Surgery is indicated however if subluxation of a joint occurs during the process of correction of the contracture

With few exceptions, surgery is never indicated in the athetoid type of cerebral palsy Whereas spasticity is related to individual muscles athetosis is characterized by an attempt to bring an extremity into a distorted position by any muscles which can accomplish it If certain athetoid muscles or muscle groups are transplanted or otherwise operated upon the athetosis will shift to other muscles of similar function which will accomplish the same distortion as in athetosis of the finger flexors following transplantation of athetoid wrist flexors to the dorsum of the wrist Occasionally, there are true postural contractures which may require corrective surgery, such as equinus contractures of the ankle and flexion contractures of the knee and hip which have arisen as a result of delayed walking with consequent prolonged maintenance of the sitting and lying positions.

In true spasticity, surgery is employed to correct deformity which can not be corrected by conservative measures, to establish balance between antagonists which cannot be balanced satisfactorily by conservative reduction of the spasticity and strengthening of the weaker muscle groups and to stabilize joints, particularly the foot, knee, and wrist. As mentioned before a complete muscle examination is essential to determine the presence and degree of spasticity in each muscle or muscle group, and the state of the antagonists of all spastic muscles on which surgery is contemplated Facilities must be available for continued treatment and rehabilitation of the patient after operation. Surgery without adequate facilities for preoperative and postoperative rehabilitation of the cerebral palsied patient is unequivocally condemned. Proper physical therapy after operation is usually more important than the operation itself.

If after thoroughly studying the patient and observing his progress under the conservative program including bracing for an adequate period of time and after determining with certainty the status of the antagonist muscles on which surgery is considered one may justifiably proceed with the operation. Stage operations are preferable re-education and retraining being carried out for an adequate period of time between each stage In this manner one may be reasonably assured beforehand that the proposed operation will be beneficial and is exactly the procedure required. Surgical procedures are definitive and there is no turning back once they have been performed

Operations on bones are limited principally to arthrodesis of the tarsal joints (p 1320) for the purposes of correcting deformity and producing a stable weight-bearing foot. Less commonly osteotomies are performed on the femur and tibia to correct angulation or torsion of these bones (pp 1161 1369 1370) from excessive stress of overactive muscles during the period of growth

Surgery of the muscles and tendons consists of tendon transferences, tenotomies, and Z-plastic lengthening of tendons these may not only correct deformity but may aid in the re-establishment of muscle balance Surgery of the periarticular structures is confined chiefly to measures for correction of a fixed deformity of a joint.

Procedures which have been carried out on the peripheral nervous system may be enumerated as follows (a) posterior root resection (Förster) (b) sympathetic ramisection (Royle) and (c) neurectomy of the peripheral nerves (Stöffel)

Posterior Root Resection

Förster attempted to interrupt the reflex arc between afferent and efferent impulses and the spinal cord by section of the sensory nerve roots within the canal as they enter the cord, and thus lessen the spasticity of the muscles. This procedure has been abandoned.

Sympathetic Ramisection

According to White, Royle s sympathetic ramisection for spastic paralysis has been proved definitely to be physiologically unsound and based upon erroneous experimental evidence. Primarily the sympathetic nervous system has no direct control over muscle tone further the slight secondary benefits which may accrue are far outweighed by the magnitude of the operation.

Neurectomy of the Peripheral Nerves

Stöffel s neurectomy is the most direct means of attacking spastic muscles. Practically all the branches to be resected are easily accessible The operation is based upon the principle that the power of a spastic muscle may be weakened to a degree which equals that of its antagonist by resection of all or a part of its nerve fibers the extent of the resection being commensurate with the spasticity of the muscle which the nerve supplies and the power of its antagonist. Proper muscle balance must be restored by too extensive resection of the nerve, a deformity in the opposite direction might be produced. The surgical risk is almost negligible The Stöffel operation, however is a destructive one and since its results cannot be completely nullified, should be employed only after due consideration of the beneficial effect and *the possible ill effects both direct and indirect which may be produced.*

The main nerve trunks are not singly functioning units, but consist of many individual motor and sensory conduits. Further cross section of the large peripheral nerve trunks will show that motor and sensory branches to certain areas occupy relatively constant positions. By a familiarity with the internal topography of the principal peripheral nerves, therefore, those segments which supply a periarticular muscle or muscle group may be isolated and partially or completely divided as necessary In general, the technic of the procedure is as follows

Technic (Stöffel) —After exposure of the main trunk, the nerve is freed and placed under slight tension, and its sheath is incised The tract to be divided is isolated for one or two inches by incision of the connective tissue or perineurium. To determine whether this is the proper tract to the affected muscle, the nerve bundle is touched with a small electrode, thus producing a slight contraction of its respective muscle. The more spastic muscles contract under considerably weaker stimulus than those of relatively less spasticity the extent of the contracture produced by a certain stimulus provides an index to the necessary amount of resection. If possible, the nerve tract is traced to its entrance into the muscle and a portion or all of the tract is incised and removed

The original Stöffel operation being somewhat tedious and lengthy, is now seldom used Instead the nerve is generally located at its point of entrance into the muscle or division from the main nerve The common sites of neurectomy are as a rule, exposed with little difficulty

FOOT

The deformities of the foot generally associated with cerebral palsy of the spastic type are (1) equinus, (2) valgus, (3) varus (4) calcaneus and (5) spastic intrinsic muscle imbalance of the foot

Spastic equinus deformities of the foot unless severe may be corrected much more safely and satisfactorily in the child by the use of braces in older children however especially after the cessation of long bone growth and in adults surgical correction may be necessary The procedures which may be employed are neurectomy of the branches to either the gastrocnemius or to the soleus depending upon which muscle is spastic and lengthening of the tendo achillis or rarely both together

For the conservative correction of equinus deformity in the growing child a single calliper brace with a well fitting ordinary high top shoe and a round rod is employed at night As the contracture is gradually corrected the rod may be bent further forcing the correction. If the equinus is sufficient to prevent the patient from placing the foot flat upon the floor in walking a similar brace is used during the day the rod being bent to accommodate the equinus. The heel of the shoe is also elevated in order to prevent excitation of the stretch reflex as the patient walks After correction to 90 degrees, the day brace is omitted though the use of the night brace is continued the rod being gradually bent usually at intervals of eight to ten weeks until full dorsiflexion is obtained Thereafter the brace is worn at night in this position until tibial growth is complete. If use of the night brace is discontinued before this time, the deformity will recur just as it may recur following surgery unless a night brace is worn consistently In these particular patients, the deformity recurs during growth because of the bowstringing effect of the growing tibia in the face of a triceps surae muscle group which does not elongate as rapidly as the bone and because of the equinus position of the foot and ankle which is ordinarily assumed at night.

Conservative correction of the equinus deformity is preferable to surgical correction, since neurectomy of the motor branches of either the gastrocnemius or soleus muscles or lengthening of the tendo achillis will weaken the calf group unnecessarily resulting in an avoidable deformity of the calf itself.

In contemplating any surgery upon the calf muscles whether neurectomy or tendon lengthening it is of utmost importance that one determine the state of function of the antagonists, in this case the dorsiflexors of the foot and ankle. The following discussion is an example of the reasoning which must be applied to any spastic joint in determining the proper measures to be employed particularly in regard to proposed surgical procedures.

The situations which might result in an equinus of the foot and ankle are as follows

1. Spastic triceps surae group vs. spastic dorsiflexors
2. Spastic triceps surae group vs. normal dorsiflexors
3. Spastic triceps surae group vs. flaccid dorsiflexors
4. Normal triceps surae group vs. flaccid dorsiflexors
5. Flaccid triceps surae group vs. flaccid dorsiflexors

It is obvious therefore that the procedure indicated depends upon the particular muscle imbalance present in the individual case In all of these, surgery should be postponed if possible until the end of the growth period, for the reasons discussed above

In the first situation i e., spastic triceps surae vs. spastic dorsiflexion, surgery should not be performed until the end of the growth period *The contracted* triceps surae muscles should be stretched by conservative measures as previously described The use of the night brace is continued and the brace is adjusted at eight to ten week intervals until complete correction is obtained thereafter, the use of the brace is continued in the fully corrected position until bone growth is complete and there is no further tendency to deformity Surgery in the form of a tendo achillis lengthening or a neurectomy of either the gastrocnemius or soleus group would be followed by a converse deformity and for this reason is to be discouraged.

In the second situation i.e. spastic triceps surae group vs. normal dorsiflexion braces are used to correct the deformity and to prevent its recurrence during the remainder of the growth period In the event surgery is to be employed *at the end of this time too extensive resection of the nerve should be* avoided.

In the third situation, i e., spastic triceps surae group vs. flaccid dorsiflexion a neurectomy of the tibial nerve and a stabilization of the foot with a posterior bone block will probably be indicated.

In the fourth situation, i.e. normal triceps surae group vs. flaccid dorsiflexion, a tendo achillis lengthening or the Vulpius modification is indicated this should be accompanied by a stabilization of the foot and a posterior bone block

In the fifth situation i e flaccid triceps surae group vs. flaccid dorsiflexion a stabilization and posterior bone block is indicated.

In the presence of spasticity of the calf muscles, with a troublesome clonus on weight bearing the clonus may be reduced by a selective neurectomy according to the method described by Phelps. Before neurectomy is done one should determine whether the clonus arises in the gastrocnemius or the soleus, by observing the clonus with the knee in different positions. If the clonus is primarily in the gastrocnemius, the clonus will disappear or materially decrease upon flexion of the knee since the gastrocnemius is relaxed in knee flexion If the clonus arises from the soleus, changes of position of the knee will have no effect on the type or degree of clonus since the soleus arises below the knee. Even in the presence of severe clonus, lengthening of the tendo achillis at the time of neurectomy is not advisable after neurectomy alone lengthening of the tendo achillis may be found unnecessary Usually resection of only one or two branches of the nerve is sufficient to relieve the clonus. This will not seriously affect the function of the triceps surae group *Phelps* has found that neurectomy for clonus is especially valuable in spasticity arising from cerebral accidents in adults, since the procedure is not extensive and the gait is often materially improved

Technic (Phelps)—The patient is anesthetized lightly so the stretch reflex will not be completely obliterated by the depth of the anesthesia. A transverse incision three inches in length is made over the lower portion of the popliteal space The fascia is divided to the tibial nerve which lies superficial to the vessels. This incision which follows the flexion crease of the skin, is preferable in that the resulting scar does not tend to become widened and

keloidlike as does that of the longitudinal incision The first branch a purely sensory one, is not disturbed The next two branches, one on the inner and the other on the outer side of the main trunk, extend to the inner and outer heads of the gastrocnemius muscle and are usually easily located and identified These branches enter the heads of this muscle close to their origin that for the medial head divides into three twigs just before it disappears in the muscle, while that for the lateral head divides into two twigs Immediately below the origin of these nerves, a single nerve arises from the posterior surface of the tibial nerve and divides to supply one twig to each head of the soleus muscle, farther distally as it lies deep to the soleus the tibial nerve gives rise to a second branch which enters the medial head of the soleus by two twigs. The branches are tested either by means of the electric current or by

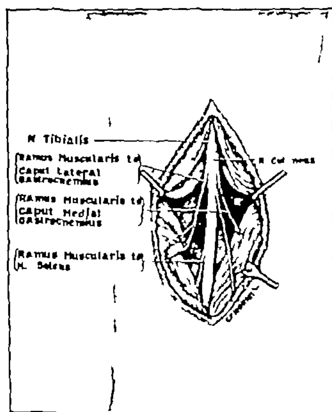


Fig 1628 —Exposure of tibial nerve and its inner and outer branches to heads of gastrocnemius and soleus muscles. The first and most superficial is a cutaneous branch. The branch to the tibialis posticus muscle comes off at a lower level as the nerve disappears beneath the soleus muscle.

gentle pressure on each of the various branches by smooth forceps. While the muscles are being tested by nerve stimulation, an assistant exerts gentle pressure in dorsiflexion against the sole of the foot. Thus the branch or branches which are especially responsible for the clonus or high degree of spasticity may be identified The selected branches are then cut off at their origin from the trunk and are avulsed from the muscle by being wound separately around a clamp

In the event one decides prior to operation to perform neurectomy of certain branches of the gastrocnemius, isolation and selective testing of the other branches is unnecessary In the occasional case wherein spasticity of the long toe flexors is of major importance the branches of the tibial nerve to these muscles may be resected.

After Treatment.—If neurectomy alone has been performed an ordinary pressure dressing is sufficient. Re-education of the dorsiflexor muscles is instituted promptly after operation, and walking is permitted as soon as the wound has healed.

In spastic paralysis the tendo achillis should always be lengthened by open operation. Subcutaneous tenotomy should never be used as the spasticity of the calf group will produce wide separation of the fragments, nonunion of the tendon and a severe secondary calcaneus deformity. The tendon is lengthened only sufficiently to permit dorsiflexion to right angle. To prevent recurrence of the deformity after operation a night brace is worn until growth of the long bones is completed. The tendon should never be lengthened if the dorsiflexors are spastic since here also a converse calcaneus deformity will follow. The ordinary lengthening of the achillis tendon should be performed only if the soleus component of the triceps surae group is contracted. *If the foot and ankle can be dorsiflexed to a right angle on flexion of the knee* a Vulpius type of procedure wherein only the gastrocnemius component is lengthened and the soleus is left intact, is indicated. This procedure prevents contraction of the soleus muscle belly and preserves its function. The following technic has been contributed by Compère.

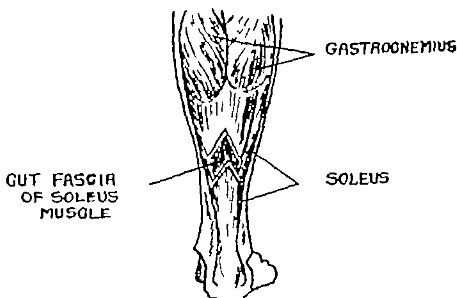


Fig. 1029.—Lengthening of tendo Achillis by Vulpius technic. (Courtesy of Drs. E. L. Compere and W. T. Schnute.)

Technic (Vulpius-Compère).—A three inch longitudinal incision is made in the mid-calf. The sural nerve is identified and retracted to one side. The fascia is exposed and a V-shaped incision is made through the fascia of the gastrocnemius; the foot is then placed in a position of slight dorsiflexion thus separating the fascial segments (Fig. 1029). If contracted the deep fascia of the soleus is also incised though the soleus muscle is not disturbed.

After Treatment.—A plaster cast is applied from groin to toes, with the knee in complete extension and the foot in the neutral or slightly dorsiflexed position. After six weeks the cast is removed and a single caliper night brace which holds the foot in right angled dorsiflexion or slightly above, is fitted. To prevent recurrence of the deformity the brace is worn until the end of the growth period.

In valgus and varus deformities particularly those which are fixed and associated with some distortion of the tarsal bones, stabilization of the foot by triple arthrodesis is carried out as for paralytic deformities. Usually, these deformities arise as a result of muscle imbalance between the peroneal and tibial muscles. In the presence of this imbalance, selective neurectomy of the nerves to the spastic muscles with tendon lengthening if fixed contractures are present, should be performed before the foot stabilization is undertaken In spasticity, just as in infantile paralysis equalization of invertor evertor imbalance is impossible by neurectomy, tendon lengthening or tendon transference If the deformity of the foot is severe incident to capsular contractures as well as to bony deformity the position of the foot should be corrected as fully as possible following the neurectomies or tendon lengthenings of the tibials or peronei by this means the extent of wedge resection and soft tissue division at the time of bone stabilization is minimized Correction is best accomplished by casts of a type similar to that employed by Kite in the correction of club foot deformities. One should also determine that the deformity has not been induced either partially or completely by an imbalance of the hip rotators. In the presence of such imbalance treatment should also be directed toward correction of the rotational deformity in order to prevent recurrence of the foot deformity after operation

Tendon transferences, as mentioned above are seldom advisable in varus or valgus deformities, since transferred spastic muscles usually fail to function in their new position and transference serve only to remove a deforming element rather than to exert a corrective force In some cases, however, the extensor hallucis longus tendon may be shifted to the head or neck of the first metatarsal to control a cock up of the great toe A posterior bone block or a Lambrinudi type of foot stabilization is a valuable adjunct if the dorsiflexors are cerebral flaccid.

Control of calcaneus deformity is difficult. The deformity usually follows ill advised lengthening of the tendo achillis either alone or in conjunction with a tibial neurectomy though it is occasionally primary in severe spasticity of the dorsiflexors of the foot and ankle with corresponding flaccidity of the triceps surae A calcaneus deformity seldom occurs in the spastic foot except in the presence of flaccidity of the triceps surae group or as a result of ill-advised surgery The force of gravity reinforced by a normal or even moderately flaccid triceps surae group generally does not permit the development of a calcaneus deformity even though the dorsiflexors are spastic. As a rule surgical correction of this deformity is unsatisfactory The dorsiflexor group if spastic should be partially neurectomized and the tendo achillis shortened by an overlapping procedure The tendon of the flexor hallucis longus or flexor digitorum longus or both should be sutured to the shortened tendo achillis in order to increase its flexor power In most cases a stabilization of the foot is necessary later to improve the associated foot deformity Thibodeau and associates state that astragalectomy has *in their hands*, given surprisingly good results in the correction of calcaneus secondary to lengthening of the achillis *tendon*

Burman has called attention to the spastic intrinsic muscle imbalance of the foot in these patients. There is usually a flexion of the toes at the metatarsophalangeal joints and extension or hyperextension at the interphalangeal joints. Contracture in the toes may be fixed. The great toe is flexed at the metatarsophalangeal joint from overpull of the flexor hallucis brevis and is

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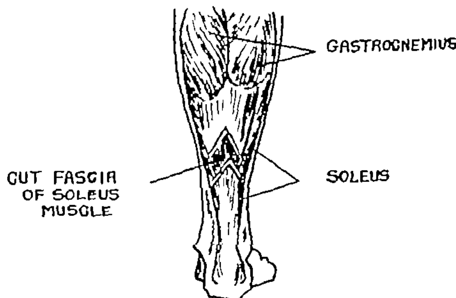


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hyperextended at the interphalangeal joint. The motor branch of the lateral plantar nerve supplies these muscles. To correct this deformity Burman advises resection of this nerve plantar capsulotomy of the metatarsophalangeal joint of the great toe and section of the heads of insertion of the flexor hallucis brevis. This deformity is seldom found in the presence of equinus of the foot and ankle.

Neurectomy of the Motor Branch of the Lateral Plantar Nerve

Technic (Burman).—The tuberosity of the fifth metatarsal bone is employed as the landmark for this procedure. A four inch longitudinal incision, beginning approximately three fourths inch proximal to the fifth metatarsal tuberosity is made in the line of separation of the central and lateral compartments of the sole of the foot. The lateral plantar nerve runs in an oblique course distally and laterally in the proximal portion of the incision, beneath the plantar fascia and between the flexor digitorum brevis and quadratus plantae muscles. Care is taken to avoid severance of the nerve and its accompanying vessels by too deep incision. The lateral plantar artery lies just proximal to the bend of the nerve. Just distal to this, the nerve runs in the space between the central and lateral compartments. The nerve is identified, and the motor branch and the twig to the fourth interosseous space are isolated. The motor branch will be found in a dorsomedial position on the common trunk of the nerve just before its division while the twig to the fourth interosseous space arises from the digital nerve branch to the fifth toe. These two nerves are then resected. A longitudinal incision is next made on the medial aspect of the metatarsophalangeal joint on the great toe. Both heads of the flexor hallucis longus are divided and the plantar capsule of the metatarsophalangeal joint is incised in order to permit correction of the flexion deformity of this joint.

After Treatment.—A plaster cast is applied from the knee to the toes, maintaining the toes in the corrected position. The cast is worn for six weeks. Upon its removal the patient is allowed to walk in a shoe from which the toe portion has been removed distal to the level of the metatarsophalangeal joints of the foot. A wedge is attached to the sole of the shoe to maintain the toes in a position of dorsiflexion and a spreader is attached to the wedge to insure separation of the great and second toes and to prevent a hallux valgus deformity. This corrective shoe is worn for two to three months.

KNEE

The deformity at the knee usually is one of flexion from an imbalance in strength and function of the flexor and extensor muscles, though occasionally the knee deformity is secondary to an adductor internal rotator or flexor deformity at the hip. At the knee plication of the patellar tendon (or distal transplantation of the tibial tubercle) for a high patella with quadriceps insufficiency and lengthening of the hamstring tendons are chiefly employed. Sciatic neurectomy and transference of the hamstring tendons into the patella are occasionally indicated.

Here again one must determine the status of all the muscles of the lower extremity which might either directly or indirectly influence the knee position, in particular the status of the knee flexors and extensors.

If the knee flexion deformity is produced by spasticity of the hamstrings in the presence of a normal or weak quadriceps group the spastic hamstrings

must be weakened by either selective neurectomy of the sciatic nerve or by hamstring lengthening though not by both If the patellar tendon has become elongated from prolonged flexion of the knee the tendon is shortened either by plication or distal transplantation of the tibial tubercle Because of the danger of growth disturbance in the proximal tibial epiphysis and consequent back knee deformity following transplantation of the tibial tubercle shortening of the tendon by plication is preferable provided the epiphyses are still open.

Green has advocated division of the iliotibial band in conjunction with lengthening of the hamstrings and in addition division of the tendinous origin of both heads of the gastrocnemius. The lengthening of the upper end of the gastrocnemius is a valuable adjunct The lengthening of the upper end of the gastrocnemius is based upon the fact that its origin from the femur is partly tendinous and partly muscular, the tendinous portion may be cut without division of the muscular portion When the foot is forced into dorsiflexion the tendinous portion will separate for a distance of three-fourths inch allowing increased dorsiflexion of the foot and facilitating correction of the flexion contracture of the knee Green has also employed "fractional" lengthening of the biceps femoris and semimembranosus in less pronounced flexion contractures of the knee the tendinous portion of these muscles are divided at some distance above the level of the knee joint leaving the muscular portion intact. Tenotomy of the hamstrings is to be condemned.

Transference of the biceps into the patella is not consistently followed by good results though this procedure probably should be employed more often in the presence of significant weakness of the quadriceps. McCarroll and Schwartzmann advocate the simultaneous transference of both the biceps and semitendinosus to prevent the lateral subluxation of the patella which may arise following biceps transfer alone

In a few cases neurectomy of the quadriceps is indicated especially for extreme spasticity of the quadriceps in association with a normal or weak hamstring group If the patellar tendon has become elongated as a result of this extreme quadriceps spasticity neurectomy of the quadriceps in conjunction with plication of the tendon or tubercle transplant is advisable to prevent a recurrence of the stretching

Occasionally hyperextension of the knee is found usually incident to damage of the upper tibial epiphysis and subsequent disturbance of bone growth or from ill-advised hamstring lengthening or tenotomy Otherwise the hyperextension generally depends upon a contracted tendo achillis associated with an imbalance between the flexors and extensors of the knee. As a rule a deformity of the proximal end of the tibia is present this should be determined by roentgenograms of the knee. The problem here is correction of the spasticity of the quadriceps by neurectomy if necessary and conservative stretching of the Achilles tendon by means of a brace as previously described. Lengthening of the Achilles tendon should be undertaken with caution since instability of the knee may follow

Neurectomy of the Sciatic Nerve

Technic.—Beginning just below the gluteal fold on the posterior surface of the thigh the incision is extended distally six inches, midway between the greater trochanter and the tuberosity of the ischium The long head of the biceps which crosses the nerve obliquely from within outward is retracted

medially On the medial side of the nerve a large branch emerges and divides into three portions, one each passing to the semimembranosus and semitendinosus muscles and to the long head of the biceps. In severe cases, all three should be resected, leaving only two-thirds of the branch to the semitendinosus. Usually two to three inches of the nerves are removed. Internal or external rotation of the tibia on the femur may be partially controlled by resection of the nerves to their respective inner or outer group

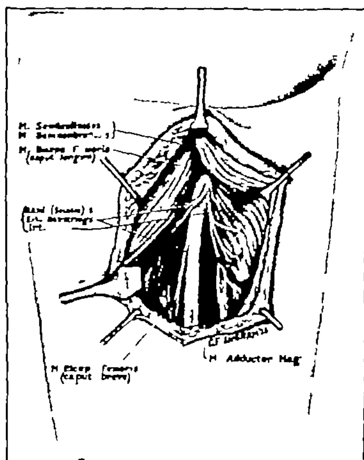


Fig 1036.—Exposure of branches of sciatic nerve to hamstring muscles. By retraction of long head of biceps to outer ide, a better exposure is obtained. All branches come from a common trunk on the medial sid of the nerve, except that to the short head of the biceps, which is distal and on the lateral side.

Patellar Advancement for Spastic Flexion Contracture of the Knee

In a limited number of cases of spastic paralysis, neither lengthening of the hamstring tendons and posterior capsulotomy nor resection of the nerves to the hamstring muscles will result in full active extension of the knee Passive motion may be normal yet active extension to more than 160 degrees will be impossible necessitating walking with the knee in *slight flexion*.

On examination, the patella will be found higher on the femur than normally (frequently over the lower portion of the shaft) and the patellar tendon will be elongated and prominent from prolonged tension during the period of growth. Because of the length of the tendon, quadriceps action in the last few degrees of extension is lost To re-establish normal leverage Fremont Chandler in 1933 described a procedure for transplantation of the tibial attachment of the patellar tendon to a point sufficiently distal on the tibia to insure tension of the quadriceps femoris muscle when the knee is fully

extended Prior to this procedure any flexion deformity of the knee must be corrected, either by wedging corrective casts, if of a mild degree or by lengthening of the hamstrings and even posterior capsulotomy

Technic (Chandler) —A vertical incision is begun lateral to the patella at a point several inches above the knee joint, carried distally along the lateral border of the quadriceps tendon and patella crossed over the patellar tendon, thence continued distally along the medial aspect of the tibia Incisions are made paralleling the entire length of the patellar tendon medially and laterally The patellar tendon is then separated from all soft tissue attachments, only its insertion into the tibial tubercle being undisturbed This may be accomplished without entering the knee joint

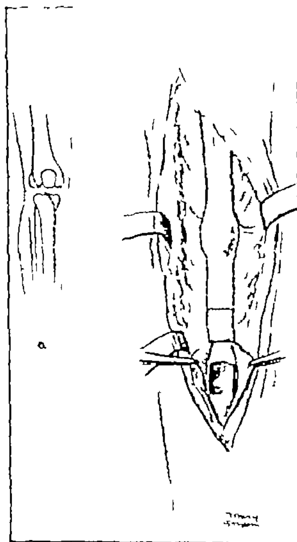


Fig 1031.—Chandler operation f re-establishment of normal leverage of patella in spastic knee flexion deformity a Patellar tendon is freed a indicated by dotted line. (From Chandler F A. Surg Gynec. Obst. 57 523 October 1933)

A block of bone with the insertion of the patellar tendon intact is removed at the tibial tubercle By division of the aponeuroses of the vastus medialis and vastus lateralis muscles, the patella is mobilized and the patellar tendon and block of bone are drawn distally as far as possible onto the tibia usually this is a distance of one and one-half inches. The periosteum at this point is incised and elevated, and a second block similar in size to the first is taken from the tibial cortex The attachment of the patellar tendon is then

countersunk into this distal recess in the tibia and fixed by mattress sutures through the periosteum over the block The second block of bone is transplanted into the cavity at the tibial tubercle. The aponeuroses are then resutured to the tendon and patella.

After Treatment.—With the knee fully extended, the extremity is immobilized in a cast from the crest of the ilium to the toes. The cast is re-

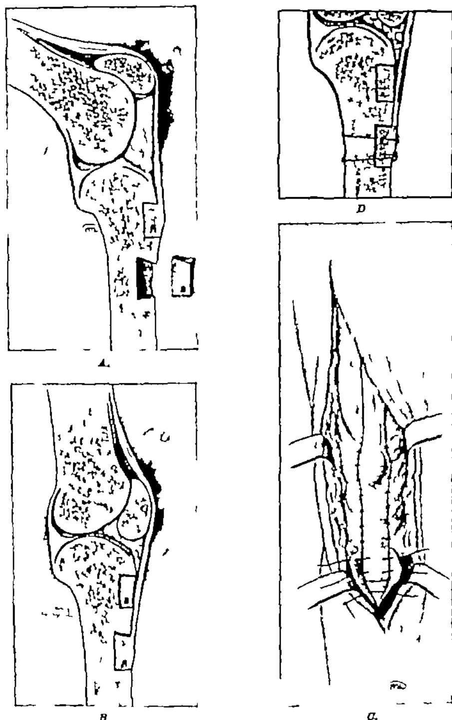


Fig. 1032.—Same as Fig. 1031 *A* Sagittal section through knee before advancement of insertion of patellar tendon. Tendon is transposed to distal recess (*B*) in tibial surface. *B*, After advancement of patellar tendon, bony fragment (*B*) fills defect created by removal of tibial tubercle (*A*) *C* Closure of periosteum over transplanted insertion of patellar tendon. Aponeuroses sutured to tendon and patella. *D* Fixation of transplanted tubercle by screws. *A B C* from Chandler F A Surg Gynec. Obst. 57 523 1933.

moved after eight weeks, and active and passive movements, physical therapy and extensive muscle re education are begun For several months, the extremity should be immobilized between exercise periods in a long night splint. Walking is resumed with the aid of a control dial knee brace at three months postoperatively Convalescence is prolonged as the patient is slow to acquire confidence in walking the gait, however is marked by complete active extension of the knee.

By the above procedure, fixation of the patellar tendon is difficult to maintain the cortex is thin and the cancellous bone soft, and a solid block of bone cannot always be secured. As the attachment must be transplanted sufficiently low to exert considerable tension fixation must be firm to prevent the spastic contracture of the quadriceps muscle from tearing the distal bone block from its new location. Two screws are placed through the transplanted tubercle and the opposite cortex of the tibia

As a means of obtaining better fixation of the transplanted tibial tubercle Bosworth and Thompson have advocated the use of a metal plate containing three holes. Two screws are passed through the transplanted tubercle mass to insure firm fixation in its new bed while the third screw is placed distally *to anchor the other two screws and to prevent their being bent by tension of* the quadriceps. All three screws must transfix the posterior cortex of the tibia

Chandler has observed recurvatum deformities following this type of procedure for patellar advancement, from interference with growth of the anterior portion of the upper tibial epiphysis. Although recurvatum has not developed in our cases after this particular operation a similar deformity has occurred subsequent to epiphyseal arrest and removal of cancellous bone in this region the anterior portion of the epiphysis ceased to grow producing an anterior tilt to the articular surface of the tibia.

Accordingly, Chandler devised a technic for patellar advancement wherein surgery is limited to the soft tissues. The patellar tendon is reefed or plicated and thereby shortened maintaining the patella in its normal position.

Technic (Chandler) —The patellar tendon is exposed by a curved bayonet incision beginning just lateral and one inch proximal to the upper border of the patella, and continuing distally and medially across the distal portion of the patellar tendon to a point about one inch below the tibial tubercle (Fig 1033 A) The center of the patella is drilled transversely and a flexible stainless steel wire is inserted (Fig 1033 *B*) A second hole is drilled transversely through the tibial crest just below the tibial tubercle A short curved cannula is next inserted beneath the aponeurosis at the lateral end of the tibial drill hole and is forced proximally beneath the aponeurosis to emerge at the lateral end of the drill hole in the patella The wire is inserted into the lumen of the cannula and the cannula is withdrawn. The procedure is repeated with the medial end of the wire and both ends of the wire are then passed through the hole in the tibia (Fig 1033 *C*) The patellar tendon is now incised in the mid line (Fig 1033 *B*) and narrow strips are cut from its free margin one strip being left attached to the patella and the other to the tibia The wire is then drawn taut and twisted bringing the patella down to its normal position in a relationship to the joint. The thin strips of tendon are threaded on a heavy fascia needle and used to plicate the remaining patellar tendon and adjacent joint capsule (Fig 1033 *D* and 1033 *E*) The plicated tendon is fixed with interrupted silk sutures.

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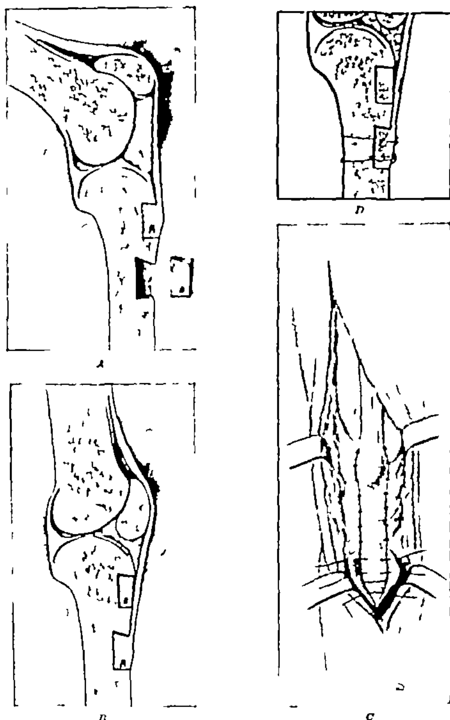


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Occasionally the quadriceps is so contracted in association with the high position of the patella that division of the proximal tendon of the rectus femoris at its origin from the pelvis is necessary. The patella may then be drawn down to its normal level.

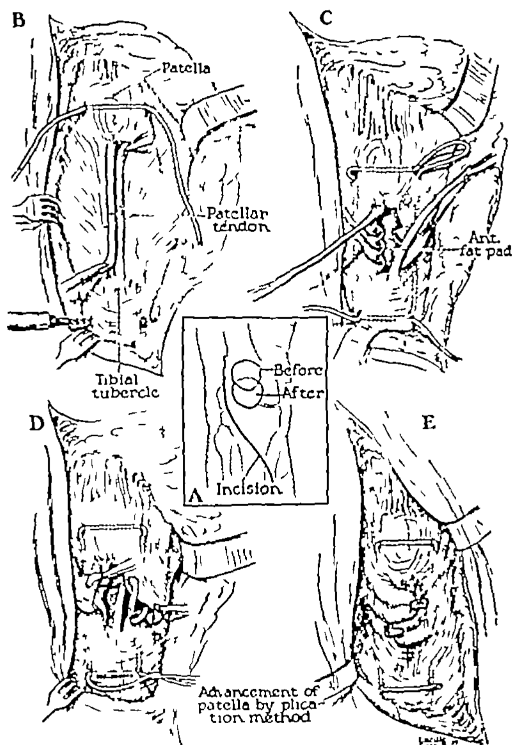


Fig. 1022.—[illegible] patella advancement by shortening of patellar tendon. A Line of skin incision. B Wire [illegible] through hole drilled transversely in patella and crest of tibia. Patellar tendon inc[illegible] [illegible] strips of tendon cut from free margin. C Both ends of wire passed through [illegible]. D Wire drawn taut, and strips of tendon laced through reduced margins of patellar tendon. E Plicated tendon fixed with silk suture. (From Dean Lewis Practice of Su[illegible] [illegible] Hagerstown, Md., 19[illegible] W. F. Prior Co., Inc.)

After Treatment.—A posterior splint is applied for several days and active motion is then begun If left in situ the wire will break, and thus should be removed after eight weeks

Transference of the Biceps Tendon for Spastic Flexion Contracture of the Knee

In this clinic the results following transplantation of the biceps femoris tendon into the quadriceps tendon to reinforce the extensor power of the knee have been almost uniformly disappointing Re education is extremely difficult and the transplant is frequently inactive With lack of proper voluntary control adequate function is almost impossible If this procedure is used, however the semitendinosus as well as the biceps femoris tendon should be transplanted into the patella as previously discussed

Technic.—See p 1354

HIP

The most common deformities about the hip are flexion internal rotation adduction and flexion It is most important that the first two be distinguished from each other since a pure adduction deformity is relatively uncommon and usually arises from spasticity of the adductors in the presence of normal but weak or cerebral flaccid abductor muscles of the hip In pure adductor spasticity the legs do not rotate internally when forcibly pulled apart As a rule flexion internal rotation deformities are produced by spastic internal rotators in the presence of weakness or flaccidity of the external rotator group The scissors gait most often results from the flexion internal rotation deformity wherein the tensor fascia lata plays a major role In such cases Phelps prefers release of the tensor fascia femoris in the form of a Soutter procedure An uncomplicated adductor spasticity will bring the legs together unless the hip flexors are similarly involved however the legs cannot cross.

The Durham procedure has been widely employed for correction of internal rotation deformity of the hip This operation has a serious disadvantage in that division of the gluteus medius and minimus muscles weakens abduction and certainly any procedure which weakens abductor power should be avoided. For internal rotation of the thighs, either of two procedures each of which has its own indications, will be found satisfactory (1) release of the internal rotators from the ilium after the method of the Soutter fasciotomy, followed by immobilization in external rotation and (2) the supracondylar rotation osteotomy If a moderate internal rotation is assumed on walking from the spasticity of active innervation deformity is not fixed and the more conservative Soutter procedure will suffice On the other hand there are cases in which the internal rotation of the thigh is constant and fixed and not merely apparent on active innervation. The rotation is produced by actual contracture of the internal rotators and the soft tissue structures about the hip itself and cannot be entirely corrected passively In older patients, structural changes in the acetabulum and the femoral head and neck may even be present. Here release of the soft tissues will not afford complete correction of the deformity because such an operation does not correct the contractures and deformities of the other structures involved In these cases a supracondylar rotational osteotomy is performed the hip and upper femur being left in the maximal degree of internal rotation and the distal fragment is externally rotated until the knee and foot are in proper alignment with the pelvis. Mc

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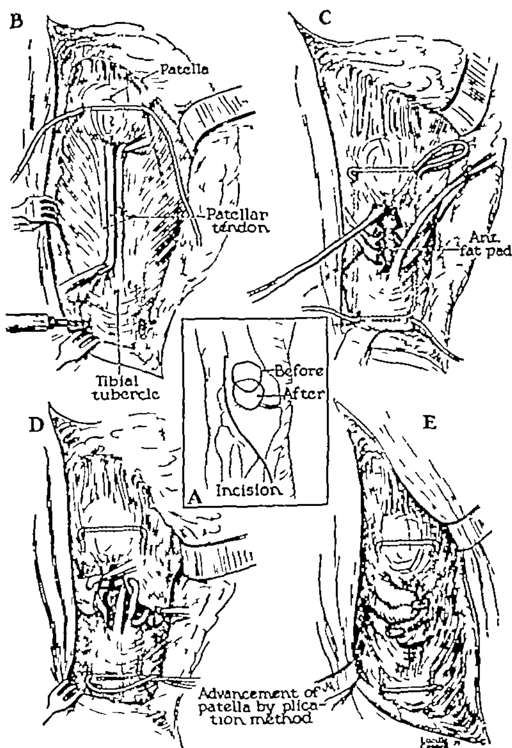


Fig. 1033.—Chandler patella advancement by shortening of patellar tendon. *A* Line of skin incision. *B* Wire passed through hole drilled transversely in patella and crest of tibia. Patellar tendon incised in midline. Strips of tendon cut from free margin. *C* Both ends of wire passed through hole in tibia. *D* Wire drawn taut, and strips of tendon laced through reduced margins of patellar tendon. *E* Plicated tendon fixed with silk suture. (From Dean Lewis' Practice of Surgery. Hagerstown, Md., 1947. W. F. Prior Co., Inc.)

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Carroll employs a transfixing wire through the proximal fragment, incorporating the wire in the cast to maintain the maximal amount of internal rotation to prevent recurrence of the deformity before union of the osteotomy is complete

Barr has advocated a procedure which is similar in principle to Legg's procedure (p 1388) whereby the tensor fascia femoris instead of being stripped from its origin and being allowed to displace and reattach distally on the pelvis is transplanted posteriorly on the ilium to convert its action into that of an external rotator and abductor

Flexion deformities of the hip in conjunction with cerebral palsy of the spastic type are not often sufficiently severe to warrant extensive operative correction Release of the flexors including the sartorius and rectus femoris by the Soutter method is usually adequate the more radical and complete procedure of transference of the crest of the ilium as described by Campbell is seldom necessary Flexion deformity due to spasticity of the psoas muscle is rare

The scissors deformity which is ordinarily considered an indication for adductor neurectomy and tenotomy may result from cerebral flaccidity of *the abductors of the hips In order to enable the patient to walk, the lower* extremities must be stabilized against each other in a scissors position. Adductor neurectomy and tenotomy in such a situation corrects the deformity but often fails to enable the patient to walk since lateral support is largely lost. It is certainly better that the patient walk with a scissors type of gait than not to walk at all Before an adductor neurectomy is performed it is absolutely essential that the hip abductors have sufficient strength to pull the legs apart actively

Intrapelvic neurectomy of the Selig-Chandler type although indicated particularly in combination with arthrodesis of the hip for spastic dislocation of the hip should be performed with caution Following complete obturator neurectomy some adductor power will be provided by the femoral nerve *which supplies the pectineus, and by the sciatic nerve which supplies* that portion of the adductor magnus arising from the ischial tuberosity and the ham strings This may be inadequate however especially if the antagonists are spastic in the latter event, the converse deformity will result An adductor neurectomy of the anterior branch of the obturator nerve alone is more conservative at the outset and later if necessary the posterior branch may be resected A second procedure may be performed again in the thigh or the intrapelvic procedure may be utilized to avoid re-entering the adductor region the latter will be scarred and identification of the posterior branch of the obturator nerve will be difficult as a result of the primary neurectomy this is particularly true if an adductor tenotomy was performed at the time of the anterior obturator neurectomy

Not infrequently the gracilis is the major deforming factor particularly in adduction deformity of the hip with an associated flexion deformity of the knee Since the gracilis is the only adductor muscle which spans both the hip and knee joints, simultaneous extension of the hip and knee will make the combined contracture more pronounced Contracture of the gracilis is best elicited according to the test evolved by Phelps, who has called attention to the importance of this muscle. The patient is placed in the prone position with the knees flexed and the thighs abducted as far as possible. The knees

are then extended gradually if the gracilis is contracted, adduction will accompany extension of the knees Often section of this muscle at its musculotendinous juncture will alone satisfactorily correct the contracture.

In severe spasticity and rigidity, wherein the adductors, flexors and internal rotators are all involved dislocation of the hip may occur Usually the paralysis is of the paraplegic or quadriplegic type rather than hemiplegic. The dislocation may be unilateral unilateral with subluxation of the opposite hip or bilateral Unilateral dislocation may be associated with an abduction external rotation deformity of the opposite hip Occasionally, a spasticity or rigidity may be complicated by a congenital dislocation Congenital dislocation is often difficult to rule out, since dislocation of the hip may occur early in these children resulting in failure of the acetabulum to develop normally in depth

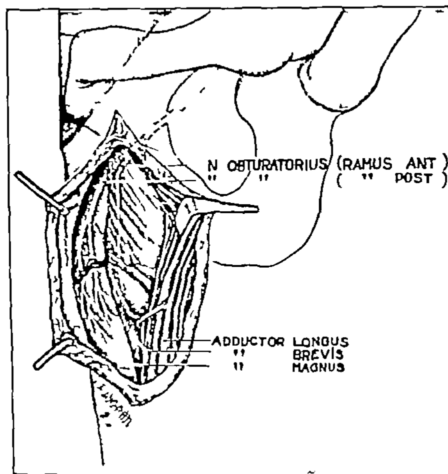


Fig. 1031 —Extrapelvic neurectomy of obturator nerves. Exposure of anterior and posterior divisions of obturator nerve vessels on surfaces of adductor brevis and magnus muscles serve as guides. Note two branches of anterior division. In mild cases, only the anterior division is resected in moderate or severe cases, both anterior and posterior divisions are resected.

The dislocation is of the posterior type with upward displacement of the femoral head. Pain is usually severe. Correction of the hip deformity by traction in so far as possible is essential before surgical treatment is undertaken. An intrapelvic obturator neurectomy however should be performed relatively early to control the pain in the hip and to reduce the adductor spasticity At the same time the gracilis if contracted should be released. Following further conservative correction by traction the crest of the ilium is transferred. A plaster spica with a Hoke-Martin traction apparatus and

well leg counter pressure is then applied to bring the head of the femur farther down toward the acetabulum in preparation for an arthrodesis which is performed as a third stage procedure In unilateral dislocation shelving operations and osteotomies are notoriously unsuccessful arthrodesis is the only practical solution Because of the shallowness of the acetabulum, some form of internal fixation such as Knowles or Moore pins, is necessary to prevent redislocation of the hip during the period of immobilization following arthrodesis. In bilateral dislocation a Schanz type of subtrochanteric osteotomy must be performed instead of an arthrodesis

Neurectomy of the Obturator Nerves

Neurectomy of the obturator nerves may be carried out through an extrapelvic or intrapelvic route Through the extrapelvic approach tenotomy of the insertions of the adductor tendons is easily accomplished

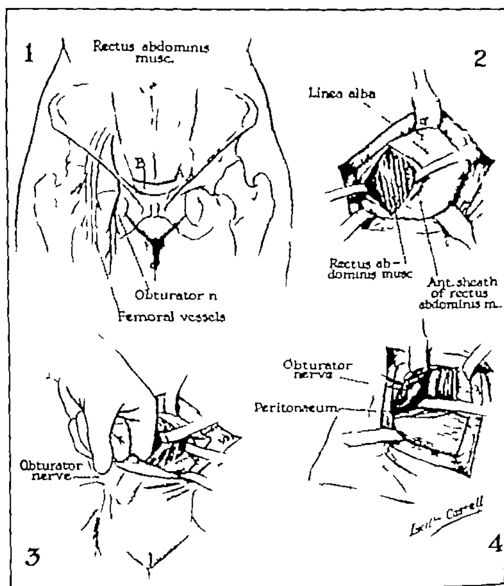


Fig. 1033 —Intrapel n ectomy of obturator nerve (Chandler) 1. A Pfannenstiel incision. B, Incision through ectus sheath. _ Sheath incised, exposing rectus abdominis muscle. 3. Lateral portion of rectus retracted medially Finger used as blunt dissector, locating nerve as it enters neural foramen of obturator fascia. 4 Obturator nerve hooked into wound and one inch of nerve resected between ligatures. (Courtesy of Dr Fremont A. Chandler)

Extrapelvic Approach—Technic.—An incision two inches in length is made on the medial aspect of the thigh beginning at the pubis and extending distally in line with the adductor longus muscle The latter is separated from the adductor brevis muscle The anterior division of the obturator nerve is located on the upper surface of the adductor brevis muscle and completely resected The adductor brevis muscle is then retracted anteriorly and the posterior division of the nerve which is found between this muscle and the adductor magnus, is also completely resected In fixed adduction contractures, the tendinous origins of the adductor muscles are severed at the proximal end of the incision Adductor force is not entirely eliminated by this procedure as a small branch of the sciatic nerve supplies a portion of the adductor magnus muscle and the pectineus muscle is preserved

Intrapelvic Approach—Technic (Chandler)—Intrapelvic obturator neurectomy has been termed the Selig operation Chandler, however has described the following technic

In bilateral resections a transverse (Pfannenstiel) incision is made in the lowest transverse skin crease just above the pubis exposing the anterior sheaths of the rectus abdominis muscles. The sheath of the rectus is then split vertically over the center of the distal portion of the muscle The lateral portion of the rectus sheath is then reflected and the lateral margin of the muscle outlined This is retracted medially The index finger is used as a blunt dissector following the posterior surface of the rectus to its insertion in the horizontal ramus of the pubis, then more deeply and laterally displacing the bladder and peritoneum posteriorly until the obturator nerve is palpated as it lies within the pelvic wall. Flat retractors are then inserted and the fatty areolar tissue is gently opened The nerve is easily located and may be identified by its position as it enters the neural foramen of the obturator fascia or by stimulation of the nerve The nerve is then separated from the blood vessels that accompany it by means of a blunt hook A ligature is placed at each of two levels along the nerve and a section of the nerve is excised Care must be taken not to tear any of the small veins, and the possibility of anomalous arteries should be kept in mind The peritoneum is permitted to fall back into place and the rectus fascia and skin are sutured.'

Postoperative fixation is unnecessary Chandler states that relaxation of the adductor group in this manner is more satisfactory than by other methods Some adduction may persist, however because of secondary innervation by the sciatic nerve.

Operation for Spastic Internal Rotation Deformity

Since the anterior fibers of the gluteus medius and minimus muscles, assisted by the tensor fasciae femoris muscle constitute the principal internal rotator mechanism of the hip release of these structures will allow correction of internal rotation deformities.

Technic (Durham)—The incision is begun at a point posterior and just proximal to the greater trochanter and carried obliquely upward and forward a distance of four inches. The tensor fasciae femoris is divided in the line of the skin incision and retracted exposing the gluteus medius and minimus muscles. By rotation of the thigh externally these structures are placed under tension and thus easily identified A grooved director is passed beneath those portions of the tendons which are inserted anteriorly below the tip of the trochanter and the tendons are divided Any remaining tight

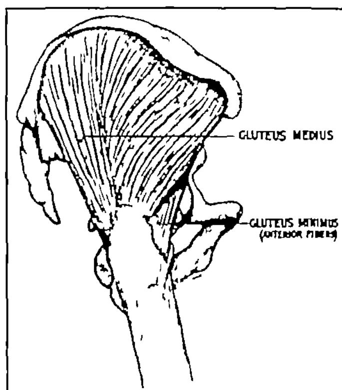


Fig. 1036.—Durham operation for spastic internal rotation deformity of hip. Insertion of gluteus medius and gluteus minimus muscles into trochanter of femur (From Durham, H. A. J Bone & Joint Surg. 20: 339 1938.)

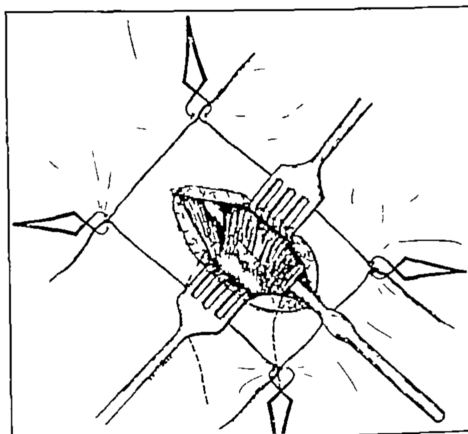


Fig. 1037.—Same as Fig. 1036. Portion of gluteus and lower border of gluteus minimus muscles isolated and divided. (From Durham, H. A. J Bone & Joint Surg. 20: 339, 1938.)

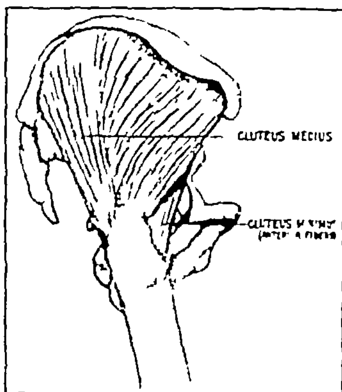


Fig 1036 —Du1am   s rati n for spa tic 1 t rn l rotation def rmity of hip. I sertion of gluteus medi   and gluteu minimu muse   into troch nter of femu   (From Durham H A. J Bon & Joint Surg 20: 39 1 38)

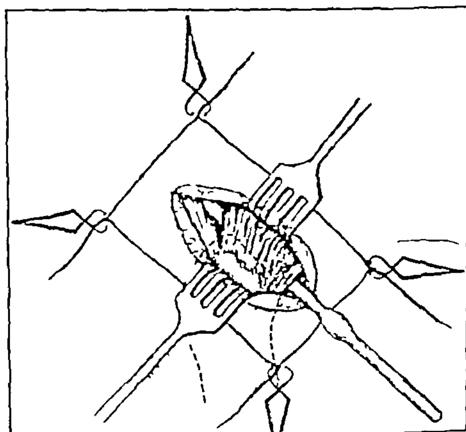


Fig. 103 —Same as F g 1 3   1 rt n f gl teu an l 1 w r bord   of gluteus minimu muscles isolated and di ided.   F om Durham, H. A.   J Bone & Joint Surg. 20: 339 1938)

fascial bands are detected by palpation and likewise incised After this procedure the thigh may be rotated externally without resistance The fascia lata if under tension and widely separated when the thigh is rotated externally is not resutured

After Treatment.—A plaster cast is applied from above the ilium to the toes on the affected side the hip being held in abduction and full external rotation When the operation is bilateral two long leg casts are applied with a connecting bar at the ankle to maintain the external rotation and abduction Six to eight weeks postoperatively the cast is removed and physical therapy and exercises are instituted



Fig 1039—Same as Fig 1036 Postoperative fixation in plaster with hips rotated externally (From Durham, H. A.: J Bone & J Int Surg 20 339 1938.)

Rotation Osteotomy for Internal Torsion of the Femur

A transverse supracondylar osteotomy of the femur is performed utilizing a lateral approach (p 17) A small Steinmann pin is inserted transversely through the proximal fragment to maintain full internal rotation of the proximal fragment at the hip while the lower fragment is correctly aligned in relation to the anterior superior spine and patella The pin is incorporated in the cast and is removed at the end of eight to ten weeks cast immobilization is continued until consolidation of the osteotomy is complete

OPERATIONS ON THE UPPER EXTREMITY

Involvement of isolated muscle groups is rare in the upper extremity, in most cases the lesion is diffuse The spastic deformities most often found

are flexion of the fingers flexion of the thumb with or without adduction, flexion of the wrist, pronation of the forearm, flexion of the elbow and adduction and internal rotation at the shoulder The flexion deformity at the elbow and the contractures about the shoulder are usually insufficient to warrant operation

The results of operations on the upper extremity are strikingly poor in comparison to the good results of surgery in the lower extremity In general surgical correction of deformities of the upper extremity is unsatisfactory and the improvement obtained is frequently cosmetic rather than functional Because of the intricate functions of the upper extremity it is almost impossible for any reconstructive work to fulfill the purpose for which it is intended Operation does not provide an initiation of movement which has been lost as a result of damage to cerebral control and will not decrease ataxia or incoordination. One cannot recommend categorically specific operative methods for the upper extremity nor propose with any degree of certainty an operative technic for each and every situation The experienced surgeons vary in their indications and preference of surgical procedures and manifest no real enthusiasm for any one type of operation

Operations on the upper extremity are designed primarily to place the arm and forearm in a functional position and to enable the patient to extend the fingers and wrist while retaining active flexion of the fingers. In many cases surgical interference is inadvisable since an injudicious operation may be followed by still further impairment of the function of the arm and hand Resection of the motor nerves in the upper extremity has a narrow field of adaptability and is confined chiefly to the relief of pronation contracture of the forearm In carefully selected cases, arthrodesis and tendon transfer offer better chances of success and occasionally give brilliant results on the whole however the outcome of these procedures is also disappointing

The Stöffel operation on the median nerve is generally unsatisfactory in that the power of extension of the fingers and wrists usually fails to return As a rule transference of the wrist flexors to the finger extensors results in good extension of the metacarpophalangeal joints though the flexion deformity of the interphalangeal joints will persist extension of these latter joints being a function of the interossei and lumbricales rather than of the long finger extensors The good results obtained by tendon transference in radial nerve paralysis, wherein the interphalangeal joints can be extended through the action of normal muscles innervated by intact median and ulnar nerves cannot be expected in spasticity Arthrodesis of the wrist, either alone or in combination with transference of the tendons gives better results than tendon transference alone only 50 per cent of these procedures however are followed by functional improvement. Many patients have fair function despite a flexed position of the wrist, since by flexing the wrist they are able to extend the fingers. This type of hand is best left alone Transference of the pronator teres into the extensor carpi radialis longus muscles is a valuable procedure at times in that an active deforming muscle is converted into an extensor of the wrist. In such cases the flexor carpi ulnaris tendon should be transferred into the ulnar extensor of the wrist to prevent radial deformity at the wrist. If structurally contracted the pronator quadratus may be easily divided. Transfer of the flexor carpi ulnaris around the ulnar aspect of the forearm and into the radius as described by Steindler or the modification described by Green wherein the flexor carpi ulnaris is transferred into the radial ex

tensor of the wrist is also excellent in that either removes a deforming element These procedures however are not often followed by active supina tory function of the transferred muscle

In opposition adduction and flexion spasticity of the thumb the neurectomies are usually *disappointing The thumb and index metacarpal fusion by* means of either a tibial or iliac graft as advocated by Thompson is frequently helpful in improving the appearance and function of such a hand.

SHOULDER

Spasticity of the shoulder generally produces adduction and internal rotation deformities The spasticity of the muscles of the shoulder girdle is not amenable to the Stoffel neurectomy as the motor nerves are rather inaccessible For this reason the only surgery which is applicable to the shoulder is the Sever operation and similar procedures as performed for obstetrical paralysis (p 1506)

ELBOW WRIST FINGERS

Contracture of the flexor and pronator muscles is responsible for the usual deformities of the elbow in spastic paralysis. The wrist and fingers generally are flexed and the thumb adducted As good function of the elbow is compatible with a slight degree of flexion no attempt is ordinarily made to reduce spasticity or to lengthen the tendon of the biceps muscle Instead surgery is directed toward correction of the pronator contracture of the forearm and flexion contracture of the wrist and fingers This may be accomplished by two different procedures tendon transference and neurectomy Tendon transference is more effective the stronger pronator or flexor muscles being transferred to act as extensors of the wrist in order to equalize the power of antagonist and protagonist The results of neurectomy of the median and ulnar nerves are less successful than similar measures in the lower extremity where movements are not so complicated

Neurectomy of the Median and Ulnar Nerves

Technic (Stöffel).—The median nerve which lies between the biceps tendon and the pronator radii teres muscle is approached through an incision over the anterior aspect of the elbow The first branch to the pronator radii teres, emerges just above the muscle The second branch supplies the flexor carpi radialis and the palmaris longus muscles. The third branch passes to the flexor carpi radialis and the flexor digitorum sublimis muscles and is often fused with the fourth branch which also supplies the flexor digitorum sublimis muscle The number of nerves resected, as well as the amount of each depends upon the degree of the spasticity If the wrist contracts to a right angle with each voluntary effort one inch of both the first and second branches may be removed as the muscles receive supplementary fibers from other branches Because of the tendency towar[illegible] nar deviation of the wrist in spasticity however the action of the ra[illegible] of the wrist should be preserved Further it is better to utilize th[illegible] in transplantation than simply to destroy it[illegible] In severe cas[illegible] d and fourth branches are resected prov[illegible] resence of th[illegible] ich is previously determined In view [illegible] bility of seri[illegible] ing the rip partial resection of branch[illegible] uperficial an[illegible] er fle[illegible] ould be

Ramus 2 to { Pronator teres (caput ulnare) / Flex. carpi radialis / Palmaris Longus

Ramus 3 to (Flex. carpi rad. / " dig. sublimis

Ramus-1 to (Pronator teres)

Rami-4,5 to (Flex. dig. sub.

M. Biceps

M. Brachialis

M. Pronator teres

M. Flex. carp. rad.

M. Palmaris Longus

M. Flex. Dig. Sublimis

Fig. 1040.—Exposure of median nerve showing branches to flexor muscles of wrist and fingers. The third and fourth branches are often combined in one trunk. First and second branches resected, and in severe cases also third, with as much of fourth and fifth as is deemed necessary

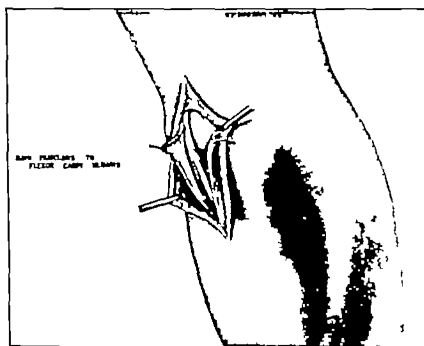


Fig. 1041—Ulnar nerve exposed at elbow Both branches to flexor carpi ulnaris muscle, which arise from a common trunk on posterior surface of nerve are resected.

avoided *As stated above the results from neurectomy in the upper extremity* are usually unsatisfactory from a functional standpoint Tight flexor spasm may be relieved though active extension is seldom improved unless definite function in these extensors can be elicited prior to operation and their function improved by muscle strengthening exercises both before and after surgery The wrist should be immobilized in extension for a time before neurectomy is performed that any improvement in function to be expected after operation can be proved before operation If this improvement fails to be maintained and deformity recurs after the splinting is discontinued, then the operation may be performed with a reasonable prospect of success

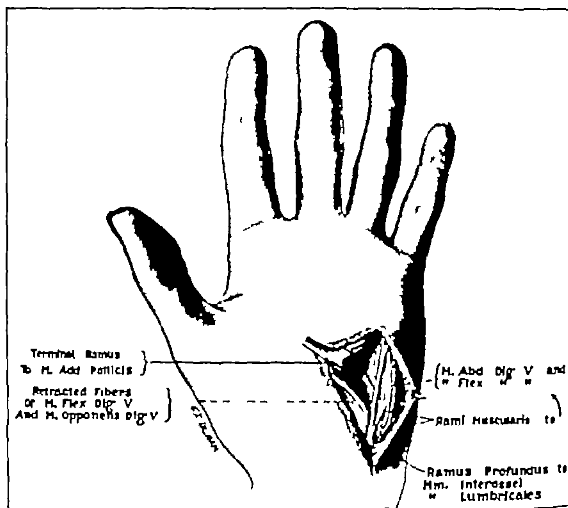


Fig 1012 —Exposure of deep branch of ulnar nerve Care should be exercised to avoid injury to small branches supplying the abductor and flexor muscles of the fifth finger Terminal branch resected just beyond limit of exposure

The ulnar nerve is exposed in its groove on the internal epicondyle of the humerus and traced downward along the edge of the flexor carpi ulnaris muscle Two small branches enter the muscles these may be completely resected

Frequently the thumb is contracted across the ... the hand preventing closure of the fingers. Correctio... es re... e *terminal* fibers of the deep branch of the ulnar ne... ... ctor muscles of the thumb The ulnar side of t... ... ial and deep

branches of the ulnar nerve are identified and the deep branch is followed downward between the flexor and adductor muscles of the fifth finger The fibers of the opponens digiti quinti muscle are separated and the nerve is traced across the palm the dissection being confined to the upper and palmar side of the nerve in order to disturb as little as possible the distal or lower side from which the branches to the intrinsic muscles arise The deep branch is explored to its division beyond the midline of the palm and the terminal branches are resected

After Treatment.—The elbow is immobilized at a right angle with the forearm in supination and the wrist in slight extension Muscle re-education is begun immediately after the wounds have healed Between exercise periods, and particularly at night the use of the splint should be continued indefinitely or until adequate function is restored

Tendon Transplantation for Mild Spastic Pronation Contracture of the Forearm and Severe Flexion Contracture of the Wrist

A spastic pronation contracture may be improved by transference of the pronator radii teres muscle into the extensor carpi radialis longus and brevis muscles. This procedure releases the spastic pronator and utilizes its power to dorsiflex the wrist (Also see technic of Tubby p 1424 and of Mayer p 1424)

Technic.—An incision four inches in length is made along the lateral border of the radius at its mid portion. The extensor carpi radialis muscles are retracted dorsally exposing the radial attachment of the pronator radii teres this is severed and sutured to the tendons of the extensor carpi radialis brevis and longus muscles.

For severe flexion contracture of the wrist a second incision is made along the lateral aspect of the distal end of the radius, and the tendon of the flexor carpi radialis muscle is exposed and divided near its insertion. The tendon is then placed within the sheath of the extensor carpi radialis longus and sutured to the tendon of this muscle.

If desirable the above procedure may be supplemented by transference of the flexor carpi ulnaris muscle into the extensor carpi ulnaris.

After Treatment.—By means of a cast the forearm is immobilized in supination, the wrist in hyperextension, and the elbow in 90 degrees' flexion. After three weeks, the cast is removed and physical therapy is instituted

Steindler has found the older technics for spastic pronation deformity wherein the pronator teres and pronator quadratus muscles are resected to be inadequate even when supplemented by transplantation of the flexor carpi radialis and pronator radii teres muscles to the radius. He therefore mobilizes the flexor carpi ulnaris at its point of insertion passes the tendon obliquely over the dorsal surface of the forearm and anchors the tendon into the lateral aspect of the lower end of the radius, thereby converting a deforming force into one of correction Before the transplantation any existing pronation contracture must of course be corrected by either use of the Funsten pronation splint or by appropriate surgery

Technic (Steindler)—If the elbow can be extended the procedure is carried out with more ease with the patient in the prone position and the arm abducted on an arm board A longitudinal incision two inches in length is made over the distal end of the tendon of the flexor carpi ulnaris, and the tendon is severed from its insertion into the pisiform bone The tendon is

avoided As stated above the results from neurectomy in the upper extremity are usually unsatisfactory from a functional standpoint Tight flexor spasm may be relieved though active extension is seldom improved unless definite function in these extensors can be elicited prior to operation and their function improved by muscle strengthening exercises both before and after surgery The wrist should be immobilized in extension for a time before neurectomy is performed that any improvement in function to be expected after operation can be proved before operation If this improvement fails to be maintained and deformity recurs after the splinting is discontinued then the operation may be performed with a reasonable prospect of success

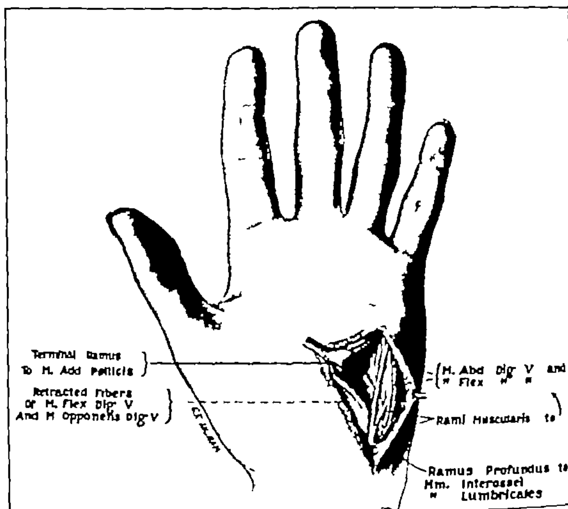


Fig. 104.—Exposure of deep branch of ulnar nerve Care should be exercised to avoid injury to small branches supplying the abductor and flexor muscles of the fifth finger Terminal branch resected just beyond limit of exposure.

The ulnar nerve is exposed in its groove on the internal epicondyle of the humerus and traced downward along the edge of the flexor carpi ulnaris muscle Two small branches enter the muscles these may be completely resected

Frequently the thumb is contracted across the palm of the hand, preventing closure of the fingers. Correction involves resection of the terminal fibers of the deep branch of the ulnar nerve which supply the adductor muscles of the thumb The ulnar side of the palm is incised the superficial and deep

branches of the ulnar nerve are identified and the deep branch is followed downward between the flexor and adductor muscles of the fifth finger The fibers of the opponens digiti quinti muscle are separated and the nerve is traced across the palm the dissection being confined to the upper and palmar side of the nerve in order to disturb as little as possible the distal or lower side from which the branches to the intrinsic muscles arise The deep branch is explored to its division beyond the midline of the palm and the terminal branches are resected

After Treatment.—The elbow is immobilized at a right angle with the forearm in supination and the wrist in slight extension Muscle re-education is begun immediately after the wounds have healed Between exercise periods, and particularly at night the use of the splint should be continued indefinitely or until adequate function is restored

Tendon Transplantation for Mild Spastic Pronation Contracture of the Forearm and Severe Flexion Contracture of the Wrist

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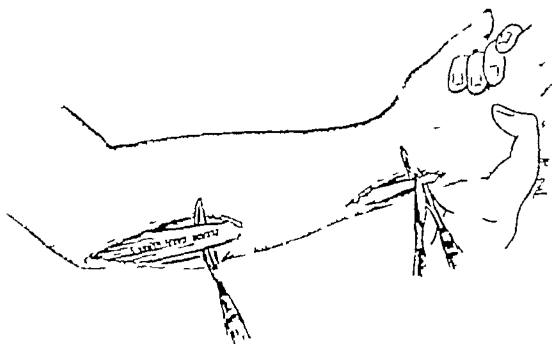


Fig 1043.—Steindler transplantation of flexor carpi ulnaris for spastic pronation deformity. Tendon isolated, detached and withdrawn proximally. (From Steindler Arthur: Orthopedic Operation, Springfield, Ill., 1940, Charles C Thomas, Publisher.)

Fig 1044.—Same as Fig 1043. Flexor carpi ulnaris tendon passed obliquely over dorsal surface of forearm and anchored into lateral aspect of lower end of radius. (From Steindler Arthur: Orthopedic Operation, Springfield, Ill., 1940, Charles C Thomas, Publisher.)

freed as far proximally as possible through this incision, with care to avoid damage to the ulnar nerve and vessels. A heavy silk suture is introduced into the end of the tendon to serve as a stay. A second incision, three and one-half inches in length, is made over the belly of the flexor carpi ulnaris muscle on the medial aspect of the forearm. This incision should begin about two inches distal to the medial humeral epicondyle and extend distally and dorsally in order to expose not only the belly of the muscle, but also the medial edge of the dorsal compartment of the forearm. The muscle is identified by traction on the suture and an incision is made through the deep fascia overlying the muscle. Dissection is carried beneath the muscle distally toward the first incision freeing the attachment of the muscle to the ulna in this region as completely as possible. A third incision approximately one and one half inches in length is made over the distal end of the radius and the radius is exposed subperiosteally in the interval between the extensor indicis proprius and extensor pollicis longus tendons. A tunnel is next drilled in the lower end of the radius for anchorage of the transplanted tendon. Attention is now again directed to the muscle. A subcutaneous tunnel is made from the distal radial incision across the dorsum of the forearm to the upper medial incision. The silk suture in the tendon of the ulnaris muscle is carried from the distal to the proximal incision by means of a tendon carrier, bringing the tendon out the proximal incision. Occasionally since the ulnaris muscle is attached almost the full distance of the ulna further dissection of the muscle from the underlying bone is necessary. In freeing up the muscle so that a straight line may be developed from its origin to its new insertion into the radius, care is taken to preserve the nerve to the muscle. Also, the opening from the ulnar to the dorsal extensor compartment should be sufficiently large to allow free entrance and passage of the muscle. The tendon is then drawn across the dorsum of the forearm into the radial incision, and is anchored through the tunnel and to itself with interrupted silk sutures.

After Treatment.—A plaster cast is applied from the palm to the axilla, with the forearm in supination and the elbow at 90 degrees. After three to six weeks the cast is removed and a Funsten pronation splint is applied. The splint should be worn until good function of the transplant is obtained usually a period of four to six months being removed meanwhile to permit re-educational exercises.

Green has described a similar transplant of the flexor carpi ulnaris though the tendon is anchored into the extensor carpi radialis longus tendon, thereby converting the transplanted ulnaris tendon into a dorsiflexor of the wrist as well as into a supinator of the forearm.

Technic (Green).—The operative plan differs from the Steindler technic only in the treatment of the distal radial incision. The extensor carpi radialis longus tendon is identified isolated, and incised and the ulnaris tendon is then sutured into it, with the forearm in supination and the wrist in dorsiflexion. The tension of the transplanted tendon should be moderate, but still sufficient to maintain the hand in the corrected position.

In an effort to prevent adduction or ulnar deviation of the wrist following transplantation of the wrist flexors into the extensors of the fingers either alone or in conjunction with arthrodesis of the wrist, Heyman has devised a method of transplantation whereby the severed tendons of the flexor carpi radialis longus and the flexor carpi ulnaris are passed between the radius and the ulna and are crossed. The flexor carpi radialis tendon is sutured to the

Fig 1043.—Steindler transplantation of flexor carpi ulnaris for spastic pronation deformity Tendon isolated, detached and withdrawn proximally (From Steindler Arthur Orthopedic Operation, Springfield, Ill., 1940 Charles C Thomas, Publisher)

Fig. 1044 —Same Fig. 1043 Flexor carpi ulnaris tendon passed obliquely over dorsal surface of f rearm and anchored into lateral aspect of lower end of radius. (From Steindler Arthur Orthopedic Operation, Springfield, Ill., 1940 Charles C Thomas, Publisher)

freed as far proximally as possible through this incision, with care to avoid damage to the ulnar nerve and vessels. A heavy silk suture is introduced into the end of the tendon to serve as a stay. A second incision, three and one half inches in length is made over the belly of the flexor carpi ulnaris muscle on the medial aspect of the forearm. This incision should begin about two inches distal to the medial humeral epicondyle and extend distally and dorsally in order to expose not only the belly of the muscle, but also the medial edge of the dorsal compartment of the forearm. The muscle is identified by traction on the suture and an incision is made through the deep fascia overlying the muscle. Dissection is carried beneath the muscle distally toward the first incision, freeing the attachment of the muscle to the ulna in this region as completely as possible. A third incision, approximately one and one half inches in length is made over the distal end of the radius, and the radius is exposed subperiosteally in the interval between the extensor indicis proprius and extensor pollicis longus tendons. A tunnel is next drilled in the lower end of the radius for anchorage of the transplanted tendon. Attention is now again directed to the muscle. A subcutaneous tunnel is made from the distal radial incision across the dorsum of the forearm to the upper medial incision. The silk suture in the tendon of the ulnaris muscle is carried from the distal to the proximal incision by means of a tendon carrier bringing the tendon out the proximal incision. Occasionally since the ulnaris muscle is attached almost the full distance of the ulna further dissection of the muscle from the underlying bone is necessary. In freeing up the muscle so that a straight line may be developed from its origin to its new insertion into the radius care is taken to preserve the nerve to the muscle. Also the opening from the ulnar to the dorsal extensor compartment should be sufficiently large to allow free entrance and passage of the muscle. The tendon is then drawn across the dorsum of the forearm into the radial incision and is anchored through the tunnel and to itself with interrupted silk sutures.

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extensor tendons of the middle ring and little fingers, while the flexor carpi ulnaris tendon is sutured to the extensor tendons of the thumb and index fingers As an alternative of this procedure the tendons may be inserted into the carpus or into the insertions of the extensor carpi radialis and extensor carpi ulnaris. Crossing of these tendons prevents or corrects the adduction deformity at the wrist

Operation for Persistent Spastic Opposition of the Thumb With or Without Flexion of Its Terminal Phalanx

Burman has suggested a rational treatment for persistent spastic opposition of the thumb This position is maintained by contracture of the muscles which form the thenar eminence namely the opponens pollicis, the flexor pollicis brevis, and the abductor pollicis brevis. Spastic flexion deformity of the terminal phalanx of the thumb is often associated. The patient may be able to abduct and extend the thumb by flexing the wrist when an attempt is made to grasp an object, however the thumb flexes and opposes into the palm preventing closure of the fingers. Since the hand is practically useless, any measure which offers hope of improvement is worthy of trial Burman's technic, wherein the common insertion of the thenar muscles is stripped reduces the leverage exerted on the thumb by the spastic muscles. For the flexion deformity of the distal phalanx the flexor pollicis longus tendon is lengthened at the wrist.

Any tendon transplantations employed in the wrist should precede the following operation to allow readjustment of the spastic hand to the new position. Further the position of the thumb may change with varying positions of the wrist.

Technic (Burman)—A longitudinal incision is made along the anterior radial border of the thumb beginning one half inch above the insertion of the thenar muscles and continuing along the length of the shaft of the first metacarpal bone. The superficial branch of the radial nerve is avoided. By subperiosteal dissection the opponens pollicis muscle is stripped from the shaft of the first metacarpal bone The insertion of the thenar muscles on the prominent tubercle on the outer side of the first phalanx is then severed and stripped proximally for at least three-fourths inch If contracted the capsule of the metacarpophalangeal joint is also severed The common tendon, which is one half to three-fourths inch long is stripped and excised.

For lengthening of the flexor pollicis longus tendon a one inch longitudinal incision is made above the wrist joint along the tendon of the flexor carpi radialis muscle The tendon of the flexor pollicis longus muscle is located midway between the flexor carpi radialis and the pronator quadratus. and lengthened in a Z-plastic manner

After Treatment.—The thumb is immobilized for three weeks in the position of abduction and extension in the plane of the hand

Operation for Spastic Adduction Contracture of the Thumb

Spastic contracture of the dorsal interosseous muscle and the adductor muscles of the thumb produces this deformity The thumb does not lie anterior to the palm of the hand

Technic (Burman)—A longitudinal incision is made along the ulnar border of the shaft of the first metacarpal bone from one-half inch above the insertions of the adductor tendons to the proximal end of the metacarpal

bone The extensor pollicis longus tendon is retracted, the digital branch of the radial nerve being avoided By subperiosteal dissection the first dorsal interosseous muscle is raised from the shaft of the first metacarpal bone The conjoined tendon of the two adductor muscles is located in the depth of the distal part of the wound and divided close to the bone

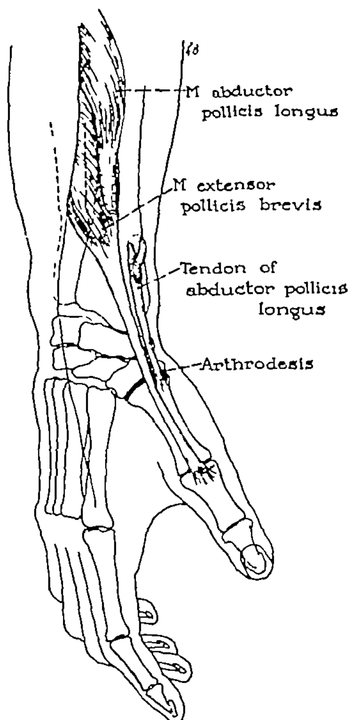


Fig 1045.—Heyman operation for adduction of thumb. Arthrodesis of first carpometacarpal joint together with tenodesis of extensor pollicis brevis to support proximal finger joint of thumb (From Dean Lewis Practice of Surgery Hagerstown, Md., 1947 W F Prior Co., Inc.)

After Treatment.—The thumb is immobilized in full abduction in a plane parallel with the fingers, and this position is maintained for a period of three weeks.

Alternative procedures have been suggested by Biesalski and Mayer who strengthen the thumb extensors by transference of the extensor indicis proprius to the extensor pollicis longus, and by Heyman who arthrodeses the carpometacarpal joint of the thumb and supports this arthrodesis with a tenodesis of the abductor pollicis longus into the lower end of the radius. The proximal stump of the long abductor is imbricated into the extensor pollicis brevis. To this, if desired, may be added a tenodesis of the extensor pollicis brevis to support the proximal phalanx of the thumb in extension.

Thompson recommends fusion of the metacarpals of the thumb and index finger for such deformities of the thumb, particularly as a last resort after the more conservative measures have failed. The technic was described by Förster in 1931 and was utilized by Allan in forty-three cases.

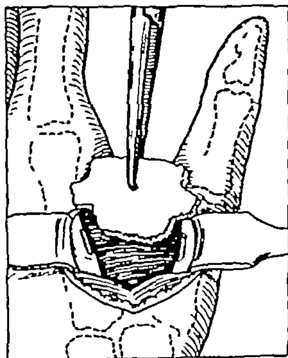


Fig. 1046.—Thompson arthrodesis of metacarpals of thumb and index finger to maintain functional position of thumb. (From Thompson, C. F.: J. Bone & Joint Surg. 24: 907, 1942.)

Technic (Thompson).—The first interosseous space is exposed through a dorsal longitudinal incision. The first dorsal interosseous muscle, whether atrophied or not, is split and preserved to cover the bone graft, while the adductor pollicis forms the bed for the graft. The radial artery should be isolated early to prevent its damage. The volar aspect of the shaft of the index metacarpal and the opposing cortex of the thumb metacarpal are subperiosteally exposed and the thumb is brought into the desired position of opposition and adduction. The adjacent surfaces of the metacarpals are marked by a small gouge and the cortices of these two bones are penetrated with a drill. The defects are elongated to a length of about three-eighths inch to form a bed for the reception of the graft. The length and size of the tibial graft to be removed is carefully gauged with the thumb in the desired position and with consideration to the "spikes" to be left on the graft for insertion into the clefts in the metacarpals. The corners of the graft are carefully removed by rongeurs and bone-cutting forceps, thus forming a keystone-shaped

block with pegs on opposite sides for insertion The graft is placed and the tension of the tissues in the interosseous space is sufficient to hold the locked graft firmly

After Treatment.—Immobilization in a plaster cast is maintained for twelve weeks The cast should be carefully molded supporting the space between the index and thumb metacarpals, and holding the thumb opposite the palm by counterpressure over the fifth metacarpal The fingers should not be incorporated, thereby permitting active use

Abbott and associates have employed iliac grafts in this procedure rather than the tibial grafts with good success.

OBSTETRICAL PARALYSIS

Whether induced by primary nerve injury or trauma to the shoulder joint at birth or a combination of the two obstetrical paralysis appears clinically as a flaccid paralysis of the entire extremity Later deformity develops from contracture of unopposed muscles. The shoulder is adducted and rotated inward, the elbow is slightly flexed and if the forearm is involved, there is pronation of the forearm and flexion of the wrist After several months, injury to the bones of the shoulder if present, may be demonstrated in the roentgenogram

Duchenne, in 1861 noted a posterior subluxation of the shoulder in some of these patients. Küstner in 1888 called attention to shoulder trauma in birth paralysis. T Turner Thomas, in 1911 attributed obstetrical paralysis primarily to an injury to the shoulder joint in the majority of cases, and nerve injury as evidenced by paralysis, to an inflammatory reaction from the trauma to the shoulder joint. He was of the opinion that trauma at birth was directly responsible for posterior luxation, which if not reduced early, would lead to changes in the bone and incongruity between the head of the humerus and the glenoid Taylor and others have demonstrated sufficient pathologic change in the brachial plexus to justify one in ascribing paralysis to a primary injury of the plexus.

Putti, in a thorough investigation of the bony changes following birth trauma observed roentgenographic evidence of bone injuries both with and without nerve lesions. If fracture occurs in the metaphysis of the humerus near the epiphyseal cartilage, the roentgenogram made immediately after birth may not reveal displacement or other abnormality another roentgenogram made several weeks later, however may show a transverse line of increased density and callus formation some distance from the epiphyseal cartilage the relative change in position of the site of injury and the epiphysis having been brought about by growth Roentgenographically trauma to the epiphysis itself is not so quickly apparent nor so obvious, after four to five months, however the roentgenogram may reveal a malshaped humeral head. Putti believes that the epiphysis may be displaced proximal to the epiphyseal cartilage plate at the time of injury and that posterior torsion of the head takes place with subsequent growth This predisposes the posterior subluxation which is sometimes present The head of the humerus may become malshaped as a result of circulatory insufficiency consequent upon trauma at or above the epiphyseal cartilage plate.

Differentiation of obstetrical shoulder trauma from obstetrical paralysis is based upon the roentgenographic findings described above particularly lateral displacement and retroversion of the epiphysis. Examinations with

faradic and galvanic currents do not reveal a nerve lesion nor muscle degeneration, although clinically the muscles are atrophied

Thus, in the opinion of several authorities, any of the following factors may have a causative relation to obstetrical paralysis

1 Primary bone injury of the shoulder as fracture damage to the epiphysis, or dislocation Patients observed after two to three years may have an affection simulating obstetrical paralysis wherein nerve function is partially or completely recovered

2. Primary rupture of the nerves of the brachial plexus.

3 Birth injuries to both bone and brachial plexus. The nerve injuries may be secondary to the reaction from the shoulder joint trauma, or both the bone and nerves may be injured at birth and independently of each other

Clinically obstetrical paralysis may be classified according to the type of nerve injury as follows (1) The upper arm or Erb Duchenne type, with paralysis of the abductors and external rotators of the shoulder flexors of the elbow, and supinators of the forearm from tearing or stretching of the fifth and sixth cervical roots usually at their junction in the brachial plexus (Erb s point) (2) the whole arm type wherein there are paralysis and anesthesia of the entire extremity following injury to all the nerves of the brachial plexus and (3) the lower arm or Klumpke type induced by injury to the lower roots of the brachial plexus from upward tension on the shoulder girdle The incidence of the upper arm type is four times that of the whole arm type or the paralysis may be of a degree varying between these two groups. The lower arm type is exceedingly rare

Patients seen within a few days or weeks after birth are fitted with a splint which maintains the shoulder in abduction and external rotation, the elbow in 90 degrees' flexion, the forearm in supination, and the wrist in dorsiflexion The splint is worn for an indefinite period of time In our experience, exploration of the brachial plexus (p 765) an operation of considerable magnitude, is seldom justified either muscle power has returned sufficiently to warrant continuation of conservative measures, or paralysis is so extensive that little can be gained by exploration Other authors believe that if there is only slight return of muscle power after three months, exploration of the brachial plexus is warranted particularly in the whole arm type of paralysis. In neglected cases, radical treatment is not instituted until the patient attains the age of four or five years a plexus operation may then be performed but is of doubtful value.

Sever Operation for Internal Rotation and Adduction Contracture of the Shoulder

When these patients come for treatment after the age of two or three years, physical therapy and other conservative measures should be carried out until they reach the age of four or five years. Abduction and external rotation are limited at the shoulder and, in some cases, close examination may reveal a posterior subluxation of the shoulder joint The acromion is generally elongated downward and forward the humerus decreased in size, the glenoid flattened and the scapula rotated and elevated as in Sprengel s deformity

The Sever operation, alone is best suited for deformities wherein there is no subluxation of the shoulder or posterior torsion of the head of the

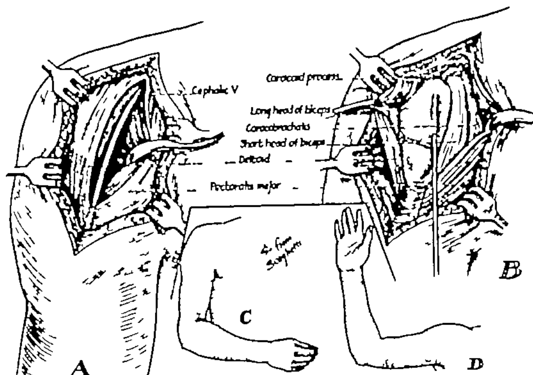


Fig. 1047.—Sever operation for internal rotation and adduction contracture of shoulder following brachial plexus palsy. *A*, Exposure between deltoid and pectoralis major muscles. *B*, Deltoid retracted laterally; pectoralis major muscle retracted medially. Tip of coracoid process, together with insertions of coracobrachialis, short head of biceps and pectoralis minor muscles detached. Lower edge of subscapularis muscle elevated with grooved director and divided without incision of capsule. Division of portion of pectoralis major, as indicated, is optional. *C* and *D*, Before and after correction of deformity.



Fig. 1048.—Before and after Sever operation for adduction and internal rotation contracture of the shoulder.

humerus. In the presence of extreme limitation of motion relatively excellent results are secured by this technic. If motion is only mildly limited, the outcome is likely to be disappointing to the parents, since, comparatively the improvement will not equal that obtained in severe cases. Sever states that the procedure is not freely undertaken in patients under four or five years of age.

Technic.—An incision is made on the anterior aspect of the shoulder from the tip of the acromion to below the insertion of the pectoralis major muscle and the latter is divided at the humerus. The deltoid muscle is then retracted laterally and the pectoralis major muscle drawn medially, exposing the coracobrachialis muscle With the arm in external rotation and abduction, the coracobrachialis muscle is traced upward to the coracoid process. As the process is usually elongated one fourth to three-eighths inch, its tip is removed together with the insertions of the coracobrachialis, the short head of the biceps, and the pectoralis minor muscles by this means, external rotation and abduction of the arm are increased. The lower edge of the subscapularis tendon is located at its attachment to the lesser tubercle elevated with a grooved director and divided completely without incision of the capsule. External rotation and abduction should then be practically normal.

A curved prolongation of the acromion may interfere with the reduction of posterior subluxation of the shoulder In this event, the portion which blocks restoration of normal relationship of the head of the humerus to the glenoid is removed, or an osteotomy is performed and the obstructing portion of the acromion elevated.

After Treatment.—With the shoulder abducted and externally rotated, the arm is immobilized in a plaster cast for two weeks. In the whole arm type the elbow is held in flexion and supination and the wrist in extension. The arm is then placed in a brace which maintains the same position, but is easily removable for physical therapy

Sever states that at best this is only a patch up procedure although results are fair none are startlingly good in the end By comparison with his previous status, however the arm is materially improved as to function.

If the latissimus dorsi and teres major muscles interfere with abduction. Steindler modifies the Sever technic by severance of the tendinous attachments of these structures through an incision along the posterior axillary fold. This, however is necessary only in severe neglected cases.

Osteotomy for Internal Rotation Deformity of the Shoulder

Vulpius, Lange and more recently Mark Rogers have performed an osteotomy of the upper portion of the humerus to correct internal rotation of the arm when there is no posterior torsion or subluxation. This procedure improves the appearance of the extremity but does not restore function as well as the Sever operation.

Technic (Rogers).—The humerus is approached anteriorly between the deltoid and pectoralis major muscles. With the arm in abduction, an osteotomy is performed two inches below the joint. To insure approximation of the fragments, the distal fragment is rotated externally through 90 degrees before closure of the wound.

After Treatment.—A shoulder spica cast which holds the elbow in 90 degrees flexion, the forearm in supination and the shoulder in 90 degrees abduction and in external rotation, is applied and maintained for eight weeks.

Operation for Posterior Torsion or Subluxation of the Head of the Humerus

For posterior torsion or subluxation of the head of the humerus Kleinberg advocated subperiosteal stripping of all structures from the upper end of the humerus, followed by rotation of the humerus externally to the proper position and immobilization in a cast while the soft parts become reattached to the bone. By this operation, the humeral head is reduced into the glenoid and the external rotators are provided with a stronger anterior attachment to the humerus. The disadvantage of the operation lies in the fact that interference with circulation may lead to aseptic necrosis of the head of the humerus or impairment of growth

Technic (Kleinberg)—The incision is made on the anterolateral aspect of the shoulder from the acromion almost to the deltoid tubercle and the fibers of the deltoid muscle are split vertically exposing the shoulder joint. The capsule and periosteum are also incised vertically to a point one and one-half inches distal to the anatomic neck of the humerus. At the distal end of the incision the periosteum is opened transversely and raised from the bone on the lateral side in this lateral flap are included the joint capsule and the tendons attached to the greater tubercle with a small segment of the underlying cartilage and bone. An inner flap is then raised which consists of the capsule and the subscapularis tendon Neither the long head of the biceps brachii nor the pectoralis major muscle is disturbed After rotation of the humerus externally the posterior flap is drawn well anteriorly fixed with a few sutures, and covered by the anterior flap The latter is then sutured without tension.

After Treatment.—The shoulder is immobilized in a plaster cast in the position of abduction and external rotation and so maintained for a period of six weeks.

Osteotomy Through the Surgical Neck of the Humerus for Posterior Torsion With Luxation of the Head

Of ninety-eight cases of obstetrical paralysis, Putti and Scaglietti ascribed sixty two to primary injury of the humerus without paralysis of the muscles Many of these patients were beyond three years of age and had definite internal rotation with adduction contracture of the shoulder and posterior dislocation of the head as a result of torsion.

The correction of this deformity is accomplished in two stages. First, the Sever operation is carried out, to maintain the shoulder in abduction and external rotation and establish the normal relation between the head of the humerus and the glenoid If the procedure were ended here, the torsion of the head would result in recurrence of the dislocation when the shoulder was brought down. After eight weeks of fixation therefore a rotation osteotomy of the shoulder is performed to correct the torsion of the head of the humerus on the shaft.

Technic (Scaglietti)—The distal portion of the incision made for the Sever operation is reopened for a distance of 5 cm. and the surgical neck of the humerus is exposed and divided with an osteotome The head of the humerus is maintained in normal relationship with the glenoid as the distal portion of the humerus is rotated internally

After Treatment.—The arm is immobilized in this position until consolidation at the osteotomy site is complete

Posterior Glenoid Abutment for Posterior Subluxation of the Humeral Head

This operation devised by John R Moore should not be undertaken until the patient reaches the age of eight years. Six weeks prior to operation, the Sever procedure is carried out to overcome the internal rotation and adduction deformity of the shoulder The day before operation, two casts are applied one to the body and the other to the arm, sufficient space being left between to expose the posterior axillary fold

Technic (Moore).—With the patient in the prone position and the shoulder abducted 90 degrees, an incision is made along the posterior axillary fold. The long head of the triceps is identified and traced upward to a point where the muscle passes between the teres major and teres minor muscles. The posterior border of the deltoid is retracted anteriorly The teres minor and infraspinatus muscles are separated throughout their length and the scapula is exposed subperiosteally These muscles are then separated from the capsule of the shoulder joint by sharp dissection By moving the head of the humerus anteriorly and posteriorly the degree of posterior subluxation of the humerus may be easily determined

A chisel, one half inch in width is driven into the glenoid and scapula at a point one-eighth inch in front of the posterior border of the glenoid, forming a cleft one half inch in depth A graft one half inch wide and one inch long is then cut from the axillary border of the scapula. With its slightly concave surface toward the head of the humerus, half the length of the graft is driven into the cleft in the glenoid

After Treatment.—The arm and body casts are joined by plaster reinforcements fixing the shoulder in 90 degrees abduction, 165 degrees extension, and 135 degrees external rotation. When the plaster is dry the patient is turned on his back and reinforcements of plaster are placed on the front, to complete the union of the two casts. After eight weeks the cast is bivalved and physical therapy and exercises, particularly of the deltoid and external rotators are begun Two weeks later an abduction brace is applied and worn for a period of three to six months, muscle training being continued meanwhile During this period the arm is brought to the side daily in order to prevent permanent limitation of motion in this direction

SPINA BIFIDA

Operative measures for spina bifida are in the province of the neurosurgeon, whereas deformities of the lower extremity associated with spina bifida are orthopedic problems. Only the lower extremities require correction, as spina bifida of the upper spine usually is a rachischisis and rapidly fatal A flaccid or spastic muscle imbalance similar to that encountered in poliomyelitis or spastic paraplegia is responsible for deformity Operative treatment described for deformities incident to those affections is therefore applicable to those associated with spina bifida Equinovarus deformity and flexion contracture of the hip joint most often require correction although flexion of the knee may also be present.

Myelomeningocele or syringomyelocele may be accompanied by a disturbance of sensation in the extremities, or even complete anesthesia. A neurologic examination should be made prior to operation, to determine the areas of anesthesia In severe cases, the neurologic disturbance is obvious, but in milder lesions with a commensurate degree of sensory impairment,

decubital ulcers may develop Or, if the deformity is an equinovarus and the surgeon is unaware of the impaired sensation, serious complications may arise from pressure for example, the usual walking casts as used in con genital equinovarus might result in necrosis of the sole of the foot or over the head of the metatarsal joints causing irreparable damage

If anesthesia of the extremities is complete operations are carried out without the use of an anesthetic

NEUROMUSCULAR DYSTROPHIES

In progressive muscular atrophy, muscular dystrophy, or pseudohyper trophic muscular paralysis and Friedreich's ataxia, the operative measures described for poliomyelitis are appropriate but rarely warranted Since these are progressive diseases, operation is always of doubtful value and at best, in the majority of cases can improve function for only a limited time.

SPASMODIC TORTICOLLIS

This affection which usually appears during middle life is characterized by a typical torticollis deformity and slow rhythmic spasms of the neck muscles. It is usually a manifestation of athetosis or dystonia and may be a part of these syndromes but is more often an isolated condition. The spasticity may vary in degree from a mild contracture of the muscles of the neck, which is exaggerated on effort to extreme tonic or clonic spasms which are completely incapacitating The etiology is unknown, though lesions of the central nervous system have been reported some following infections of the nervous system such as epidemic encephalitis The lesions described have most often been found in the basal ganglia. In addition, a psychogenic or functional type is said to exist, though differentiation between the organic and functional type is frequently impossible especially when no other evidences of generalized dystonia or athetosis are present. Various tests such as nerve block and partial anesthesia with pentothal are probably of no real value in the distinction of the two forms. If there is any suspicion that the condition is functional the patient should be referred to a competent psychiatrist for thorough survey

Surgery should be undertaken upon the patient's request, as a last resort, provided one is reasonably sure that the disease is organic and is not general ized. Complete relief of symptoms is unusual though life may be made more tolerable

It is generally agreed that only rarely will minor procedures such as tenotomies and section of the spinal accessory nerves in the neck, be of real benefit. Severe cases require major surgery namely rhizotomy of the anterior roots of the first three cervical nerves intradurally and section of the eleventh cranial nerve in the posterior fossa just as it enters the jugular foramen. In certain patients who have bilateral spasm, especially those who do heavy manual labor and those who have large heads subluxation with flexion of the upper cervical vertebrae has followed The patient s head falls forward and the mandible presses into the neck in such a manner as to inter fere with breathing swallowing and speaking Because of this Adson Young and Ghormley have combined rhizotomy of the upper three cervical anterior roots and intracranial section of the spinal accessory nerves with fusion of the occiput to the cervical spine

Technic (Adson, Young, and Ghormley).—A midline incision is made from the inion to the spine of the sixth cervical vertebra. The occiput, and the spinous processes and laminae of the first four cervical vertebrae are exposed subperiosteally. Perforator openings are made in the occiput on each side and enlarged to about one inch in diameter. The dura is opened and the cerebellum is retracted medially, exposing the ninth, tenth, and eleventh cranial nerves as they enter the jugular foramen. The eleventh nerve is sectioned bilaterally and the dura is closed. The laminae of the axis and atlas are then removed and the dura over the cervical cord is exposed. The dura is opened vertically and the first, second, and third anterior roots are sectioned bilaterally. (The authors point out that the first cervical anterior roots may be overlooked since they lie directly anterior to the vertebral arteries as they enter the cranial cavity.)

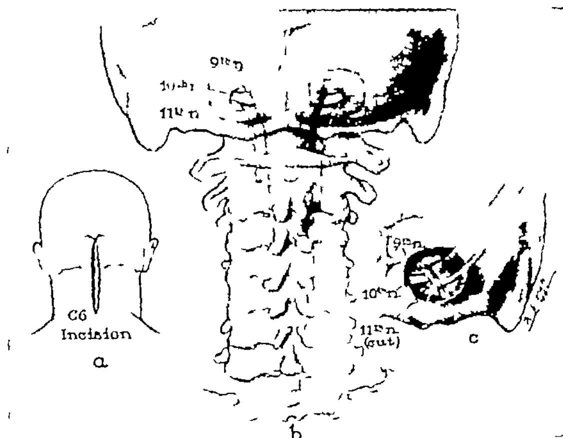


Fig. 1049.—Rhizotomy and fusion for spasmodic torticollis. *A*, Line of skin incision to expose occipital bone and upper portion of cervical spine. *B*, Position of two trephine craniectomies for section of spinal accessory nerves. *C*, Detail of intracranial section of spinal accessory nerve. (From Adson, A. W., Young, H. H., and Ghormley, R. K.: J. Bone & Joint Surg. 28: 299, 1946.)

As in all rhizotomies it is mandatory that one spare all lar... in the roots. Failure to do so will occasionally result in inad... supply to or thrombosis in the cord which at this level would be... hardly necessary to warn against bilateral simultaneous section ... cervical anterior root as well; this usually results in bilateral phre... and serious if not fatal respiratory embarrassment. The dura is... interrupted silk sutures.

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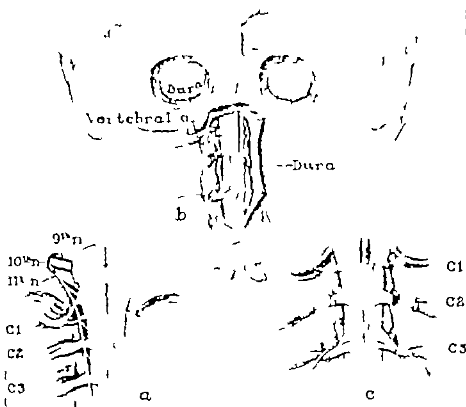


Fig. 1050.—Same as Fig. 1049. *A*, Relationship of upper three cervical nerves to vertebral artery and spinal accessory nerve. *B*, *C*, Bilateral rhizotomy of first and second cervical nerves, and motor root of third cervical nerve. (From Adson, A. W., Young, H. H., and Ghormley, R. K.: J. Bone & Joint Surg. 28: 299, 1946.)

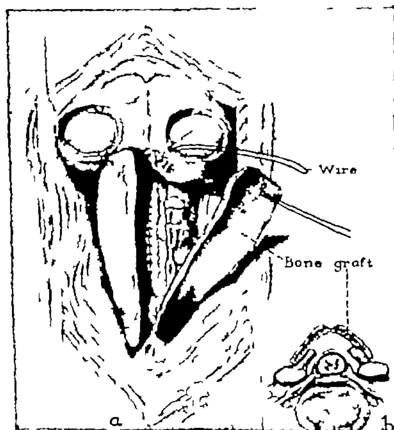


Fig. 1051.—Same as Fig. 1049. *A*, Fusion of occiput to cervical spine accomplished by iliac grafts. *B*, Relation of bone graft to area of laminectomy. (From Adson, A. W., Young, H. H., and Ghormley, R. K.: J. Bone & Joint Surg. 28: 99, 1946.)

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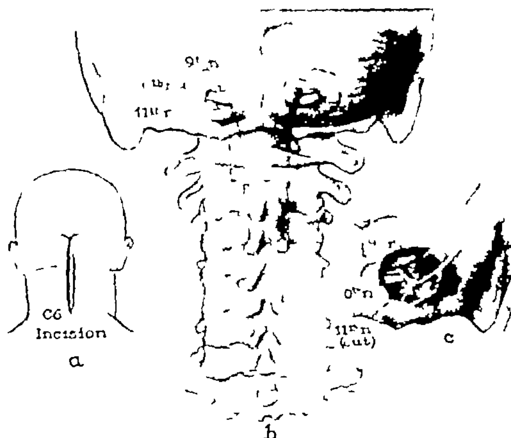


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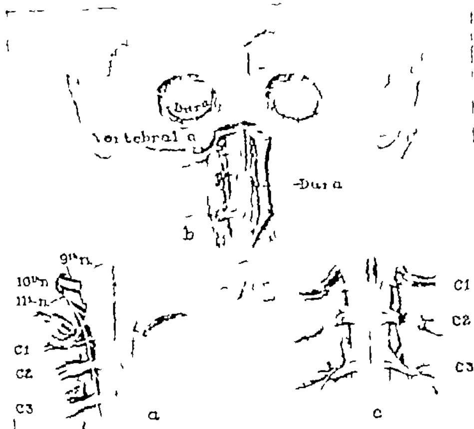


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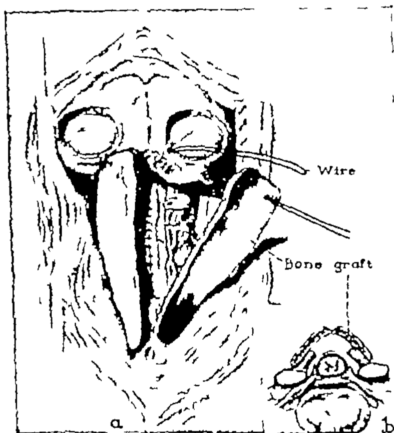


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over the exposed spinal canal The proximal ends of the grafts are anchored to the skull by wire loops. The lower ends of the grafts are fixed to the denuded spinous processes and laminae by suture of the adjacent muscles in their normal positions

After Treatment.—A cast is applied from the head to the iliac crests. Plaster fixation is maintained for 12 weeks A metal and leather support is worn for an additional three months

References

Cerebral Palsy

Allan F G: Personal communication to Thompson C F., Fusion of the Metacarpals of the Thumb and Index Finger to Maintain Functional Position of the Thumb, J Bone & Joint Surg 24 907 1942.
Barr J S: Muscle Transplantation for Combined Flexion Internal Rotation Deformity of the Thigh in Spastic Paralysis Arch. Surg 46 605, 1943.
Bosworth D M., and Thompson F R: Fixation of the Transplanted Tibial Tubercle, J Bone & Joint Surg 28 55 1946.
Borman M S: The Spastic Hand, J Bone & Joint Surg 20 133 1938
—: Spastic Intrinsic Muscle Imbalance of the Foot J Bone & Joint Surg 20 145, 1938
Carrell W B: Sympathetic Ramisection in Spastic Paralysis J A. M A. 96 849 1931.
Chandler Fremont A On Obturator Neurectomy (Personal communication.)
— Reestablishment of Normal Leverage of the Patella in Knee Flexion Deformity in Spastic Paralysis Surg Gynec Obst. 57 523 1933.
Chandler F A: Patellar Advancement Operation; A Revised Technic J Internat. Coll. Surgeons 3 433 1940
Chandler F A Lecture on Operative Treatment of Cerebral Palsy Am. Acad. Orthop Surgeons Meeting Chicago, Jan., 1941
Cleveland M., and Bosworth D M Surgical Correction of Flexion Deformity of Knees Due to Spastic Paralysis Surg Gynec Obst. 63 659 1936.
Compere E. L.: Personal communication, 1946.
Dickson F D. The Treatment of Cerebral Spastic Paralysis, With Special Reference to the Stöffel Operation J A. M A 83 1430 1924
Dowman C. E., and Hoke Michael The Treatment of Spastic Paralysis Arch. Surg 9 145 1924
Durham, H A: A Procedure for the Correction of Internal Rotation of the Thigh in Spastic Paralysis J Bone & Joint Surg 20 339 1938
Förster O Ueber eine neue operative Methode der Behandlung spastischer Lähmungen mittels Resektion hinterer Rückenmarkswurzeln Ztschr f orthop. Chir 22 203, 1908
Green W T: Tendon Transplantation of the Flexor Carpi Ulnaris for Pronation Flexion Deformity of the Wrist Surg Gynec Obst. 75 33 1942.
Green W T., and McDermott L J Operative Treatment of Cerebral Palsy of Spastic Type J A M A. 118 434 1942.
Gill A. B: Surgery of Spastic Paralysis, Ann. Surg 67 529 1918
— Stöffel's Operation for Spastic Paralysis, Jour Orthop. Surg 3 52, 1921.
Heyman C H. The Surgical Treatment of Spastic Paralysis, Dean Lewis Practice of Surgery Vol. III Hagerstown, Md., 1945 W F Prior Company Inc.
McCarroll, H R., and Schwartzmann J R: Spastic Paralysis and Allied Disorders, J Bone & Joint Surg 25 15 1943.
Phelps, Winthrop M: Personal communication 194
Phelps W M.: Treatment of Paralytic Disorders Exclusive of Poliomyelitis, Bancroft, F W., and Murray, C R., Surgical Treatment of the Motor-Skeletal System, Vol. I, Philadelphia, 1945 J B. Lippincott Company
Royle N D Treatment of Spastic Paralysis by Sympathetic Ramisection Proc. Roy Soc Med. (Orthopedic Sect.) 20 63, 192
— The Clinical Results Following the Operation of Sympathetic Ramisection, Brit. M. J 2 6 9, 1930.
Ryerson E. W: Cerebral Spastic Paralysis in Children J A. M A. 98 43, 1932.
Steindler, Arthur Reconstructive Surgery of the Upper Extremity New York, 1923, D Appleton & Co.
— Operations on the Upper Extremity Problems in Kinetics End Results, J Bone & Joint Surg 9 404 1927
Steindler, A Orthopedic Operations, Springfield Ill., 1940, Charles C Thomas.
Stöffel, Adolf The Treatment of Spastic Contracture Am. J Orthop. Surg 10 611 1912 13.
Thibodeau, A A Wagner L. C., and Carr F J., Jr The Evaluation of Surgical Procedures on Bone Muscles and Peripheral Nerves in Spastic Paralysis Am J Surg 43: 821 1939

Thompson, C. F Fusion of the Metacarpals of the Thumb and Index Finger to Maintain Functional Position of the Thumb J Bone & Joint Surg 24 907, 1912
Vulpius, O., and Stöffel, A.: Orthopadische Operationslehre ed. 2 Stuttgart 1920 Ferdinand Enke

Obstetrical Paralysis

Kendrick, J L: Changes in the Upper Humeral Epiphysis Following Operations for Obstetrical Paralysis J Bone & Joint Surg 19 473, 1937
Kleinberg S.: Reattachment of the Capsule and External Rotators of the Shoulder for Obstetric Paralysis, J A M A 98 291, 1932
Moore J R.: Bone Block to Prevent Posterior Dislocation of the Shoulder (Personal communication)
Platt, Henry Opening Remarks on Birth Paralysis J Orthop. Surg 2 272 1920
Rogers, M. H. An Operation for the Correction of the Deformity Due to Obstetrical Paralysis ' Boston M & S. J 174 103 1916
Scaglietti, O Lesioni ostetriche della spalla, Chir d. org di movimento 22 183 1936.
—: The Obstetrical Shoulder Trauma Surg Gynec Obst 66 868 1938.
Sever, J W: Obstetric Paralysis, Am. J Dis. Child 12 541, 1916.
— The Results of a New Operation for Obstetrical Paralysis, Am. J Orthop. Surg 16 248 1918.
— Obstetric Paralysis, J A. M. A. 85 1862, 1925.
— Obstetrical Paralysis, Surg Gynec. Obst. 44 547 1927
Taylor, A. S.: Results From Surgical Treatment of Brachial Birth Palsy J A. M A. 48 96 1907
— Brachial Birth Palsy and Injuries of Similar Type in Adults, Surg Gynec. Obst 30 494, 1920
Thomas T T: Laceration of the Axillary Portion of the Capsule of the Shoulder Joint as a Factor in the Etiology of Traumatic Combined Paralysis of the Upper Extremity Ann. Surg 53 77, 1911
— Obstetrical or Brachial Birth Palsy Am. J Obst. 73 577, 1916.
— Traumatic Brachial Paralysis With Flail Shoulder Joint, Ann. Surg 66 532, 1917
—: Brachial Birth Palsy: A Pseudoparalysis of Shoulder-Joint Origin Am. J M. Sc. 159 207 1920

Spasmodic Torticollis

Adson, A. W., Young H. H., Ghormley, R. K. Spasmodic Torticollis. Severe Organic Type Treated by Combined Operation Rhizotomy and Fusion J Bone & Joint Surg. 28 299, 1940.
Finney J M T., and Hughson, Walter Spasmodic Torticollis, Ann. Surg 81 255, 1925.
Keen, W W: A New Operation for Spasmodic Wry Neck, Ann. Surg 13 44 1891
McKenzie, K. G Intrameningeal Division of the Spinal Accessory and Roots of the Upper Cervical Nerves for the Treatment of Spasmodic Torticollis, Surg Gynec. Obst. 39 5 1924.

CHAPTER XXIV

STATIC OR POSTURAL AFFECTIONS

A large proportion of the deformities which the orthopedic surgeon is called upon to treat belong to the postural group The weight of the body through gravity exerts a constant pressure downward which, under normal conditions, is distributed evenly throughout the spine and lower extremities static or postural defects are brought about by the action of the force of gravity on abnormal structures or by increased weight on normal structures. The bones of the spine and lower extremities, being the only portions of the skeleton concerned with weight bearing are naturally the regions involved.

Not infrequently, static affections begin in childhood ye are not noticeable before adolescence or cause no symptoms until early adult life. The body weight of the young child is light and occupation plays an insignificant role. As the weight increases, however and occupations are assumed which require prolonged sitting or standing the deformity generally becomes pronounced. If discovered early and properly treated correction may often be obtained and disability later in life prevented Only those affections which necessitate operative correction will be discussed herein

PES PLANUS

Pes planus, or flat foot may be induced by any abnormality of congenital or acquired origin which alters the contours of the bones of the longitudinal arch impairs the tonicity of the muscles of this arch particularly the tibialis anticus and posticus or reduces the efficiency of the plantar ligaments. Pes planus or planovalgus deformities caused by fractures, or associat[illegible] fantile paralysis or spastic cerebral paralysis will not be cons[illegible] discussion will be limited to the common form of pes planus, whi[illegible] congenital origin or of static origin superimposed upon [illegible] variations of the structures of the foot such as prehallux

Clinically pes planus may be classified as (1) flexible [illegible] spastic, and (3) rigid The first type is evident principally on [illegible] the normal position can be assumed voluntarily with little [illegible] type is characterized by spasticity and shortening of t[illegible] as a reflex response to painful tarsal joints In the [illegible] some evidence which tends to invalidate the presen[illegible] of spastic flat foot and consequently the treat[illegible] study attributed the etiology to a lesion of the [illegible] ment or of the subastragalar joint the reflex [illegible] secondary phenomenon to relax the ligament [illegible] possible either passively or actively this dep[illegible] deformity adaptive changes in the bones and [illegible] of pain induced by attempts at correction. [illegible] may be accomplished by manual force while the [illegible] by successive casts.

Rigid pes planus cannot be corrected either [illegible] even the use of manual force under anesthesia

type which usually evolves from neglected flexible or spastic pes planus, possibly associated with secondary arthritic changes, is rarely observed in children under twelve or fourteen years of age. The degree of deformity and mechanical disturbance of the foot varies from mild depression of the arch and slight eversion to extreme planus. In the average severe planus or planovalgus, the forefoot is in abduction and slight supination the arch depressed, the scaphoid and head of the astragalus are prominent on the medial aspect of the foot and the os calcis is everted particularly as viewed from the rear In addition the os calcis is angulated medially, the posterior extremity being slightly lateral to its normal position and the anterior extremity toward the medial side of the foot. The relation of the astragalus and os calcis is altered, in that the former is angulated forward downward and medially When this deformity is of long standing the bones, especially the scaphoid and medial cuneiform are distorted to conform to the abnormal position Secondary changes take place also in the soft tissues the plantar ligaments the tibial tendons and even the deltoid ligament of the ankle are stretched and the peroneal tendons and usually the tendo achillis are commensurately shortened.



Fig. 1012.—Pes planus, with abduction of forefoot and marked eversion of os calcis. Considerable pain after rigorous exercise or walking across rough ground.

Undoubtedly, there are many patients with severe pes planus who have not availed themselves of surgical treatment, either because of the slight suffering and period of invalidism incident to the operation, or because of the expense This is particularly true of those who have not yet reached the age at which symptoms appear and surgery does not seem imperative.

The indications for surgical interference vary according to the nature and degree of the deformity as well as its duration. The type of operative procedure also should be based upon these considerations.

In children, if conservative measures are ineffectual, manual correction under anesthesia with or without lengthening of the achillis tendon may be undertaken The operation described by Kidner is applicable only to a special type of pes planus (p 1519) By recognition of the entity however many children who are eligible for this relatively simple operation may have the deformity corrected at an early age before secondary changes in the bones and soft tissues become permanent. Operations which entail fusion of the joints should not be considered in patients under ten years of age at the least, and preferably fifteen otherwise, growth will be materially impaired. Further prior to this age firm ankylosis is secured with difficulty because of the preponderance of cartilage and the small amount of cancellous tissue in the skeletal structure.

CHAPTER XXIV

STATIC OR POSTURAL AFFECTIONS

A large proportion of the deformities which the orthopedic surgeon is called upon to treat belong to the postural group The weight of the body through gravity exerts a constant pressure downward which under normal conditions, is distributed evenly throughout the spine and lower extremities static or postural defects are brought about by the action of the force of gravity on abnormal structures, or by increased weight on normal structures. The bones of the spine and lower extremities, being the only portions of the skeleton concerned with weight bearing are naturally the regions involved.

Not infrequently static affections begin in childhood yet are not noticeable before adolescence or cause no symptoms until early adult life. The body weight of the young child is light and occupation plays an insignificant role. As the weight increases, however and occupations are assumed which require prolonged sitting or standing the deformity generally becomes pronounced. If discovered early and properly treated, correction may often be obtained and disability later in life prevented Only those affections which necessitate operative correction will be discussed herein

PES PLANUS

Pes planus, or flat foot, may be induced by any abnormality of congenital or acquired origin which alters the contours of the bones of the longitudinal arch, impairs the tonicity of the muscles of this arch particularly the tibialis anticus and posticus, or reduces the efficiency of the plantar ligaments. Pes planus or planovalgus deformities caused by fractures, or associated with infantile paralysis or spastic cerebral paralysis will not be considered rather discussion will be limited to the common form of pes planus, which is of static or congenital origin or of static origin superimposed upon congenital minor variations of the structures of the foot such as prehallux.

Clinically pes planus may be classified as (1) flexible or relaxed (2) spastic, and (3) rigid. The first type is evident principally on weight-bearing the normal position can be assumed voluntarily with little effort. The spastic type is characterized by spasticity and shortening of the peroneal tendons, as a reflex response to painful tarsal joints In the recent literature there is some evidence which tends to invalidate the present conception of the etiology of spastic flat foot and, consequently the treatment. Lapidus, in a recent study attributed the etiology to a lesion of the interosseous talocalcaneal ligament or of the subastragalar joint the reflex pronator muscle spasm being a secondary phenomenon to relax the ligament. Correction may or may not be possible either passively or actively this depends upon the duration of the deformity adaptive changes in the bones and soft tissues, and the amount of pain induced by attempts at correction. As a rule, satisfactory correction may be accomplished by manual force while the patient is under anesthesia, or by successive casts.

Rigid pes planus cannot be corrected either voluntarily or passively and even the use of manual force under anesthesia may not be successful. This

type, which usually evolves from neglected flexible or spastic pes planus, possibly associated with secondary arthritic changes, is rarely observed in children under twelve or fourteen years of age The degree of deformity and mechanical disturbance of the foot varies from mild depression of the arch and slight eversion to extreme planus. In the average severe planus or planovalgus, the forefoot is in abduction and slight supination the arch depressed the scaphoid and head of the astragalus are prominent on the medial aspect of the foot and the os calcis is everted particularly as viewed from the rear In addition the os calcis is angulated medially, the posterior extremity being slightly lateral to its normal position and the anterior extremity toward the medial side of the foot. The relation of the astragalus and os calcis is altered in that the former is angulated forward, downward and medially When this deformity is of long standing the bones, especially the scaphoid and medial cuneiform are distorted to conform to the abnormal position Secondary changes take place also in the soft tissues the plantar ligaments, the tibial tendons, and even the deltoid ligament of the ankle are stretched and the peroneal tendons and usually the tendo achillis are commensurately shortened

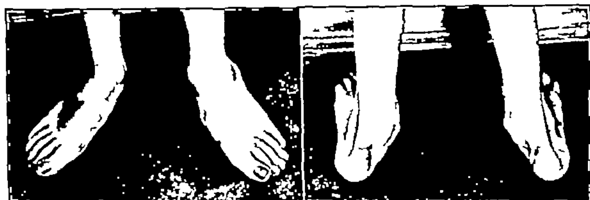


Fig. 1452.—Pes planus, with abduction of forefoot and marked eversion of os calcis. Considerable pain after rigorous exercise or walking across rough ground.

Undoubtedly there are many patients with severe pes planus who have not availed themselves of surgical treatment, either because of the slight suffering and period of invalidism incident to the operation, or because of the expense This is particularly true of those who have not yet reached the age at which symptoms appear and surgery does not seem imperative

The indications for surgical interference vary according to the nature and degree of the deformity as well as its duration. The type of operative procedure also should be based upon these considerations.

In children, if conservative measures are ineffectual, manual correction under anesthesia with or without lengthening of the achillis tendon, may be undertaken. The operation described by Kidner is applicable only to a special type of pes planus (p 1519) By recognition of the entity however many children who are eligible for this relatively simple operation may have the deformity corrected at an early age, before secondary changes in the bones and soft tissues become permanent. Operations which entail fusion of the joints should not be considered in patients under ten years of age at the least, and preferably fifteen otherwise, growth will be materially impaired. Further prior to this age firm ankylosis is secured with difficulty, because of the preponderance of cartilage and the small amount of cancellous tissue in the skeletal structure.

For flexible types of pes planus with relatively little distortion of the tarsal bones or adaptive changes in the soft tissues, the Miller Hoke and Chambers technics are particularly suitable These permit the maximum amount of correction while limiting motion to the minimum degree. In the event correction of the valgus deformity of the os calcis is not satisfactory a subastragalar arthrodesis (p 584) may be combined with the Miller or Hoke procedure, motion being preserved in the mid tarsal joints. The Miller operation has been most satisfactory and is used in the majority of instances in preference to the other procedures listed below We have been very satisfied with the results of this technic.

Operations wherein correction is secured by resection and ankylosis of one or more of the principal tarsal joints, i e., the subastragalar calcaneocuboid, and astragaloscaphoid, should not be employed in other than the most severe deformities. These joints are of prime importance in abduction and adduction and inversion and eversion of the foot They cannot moreover be regarded as independent functioning units ankylosis of the astragaloscaphoid joint alone results in practically complete loss of function of the calcaneocuboid joint, and even function of the subastragalar joint is materially impaired. On the other hand in exaggerated planus with complete rigidity of long duration resection and ankylosis of these joints may be warranted. In this type the feet are often extremely painful and arthritic changes may be present, either as a part of a generalized arthritis, or a sequela of the distorted mechanics of the foot.



Fig 1063 —After correction by Miller operation for pes planus, and Z-plastic lengthening of peroneal tendons.

The operative measures which have been devised for pes planus may be enumerated as follows

1 Manual correction with or without lengthening of the achillis tendon, followed by fixation in an overcorrected position (Robert Jones)

2. Excision of the prehallux and transference of the tibialis posticus tendon (Kidner)

3 Transference of the calcaneoscaphoid ligament, with fusion of the joints between the scaphoid the medial cuneiform, and the first metatarsal bones (Miller)

4. Arthrodesis of the joints between the scaphoid and medial two cuneiform bones by means of a graft from the tibia (Hoke)

5 Arthrodesis of the astragaloscaphoid joint and transference of the insertion of the tibialis anticus tendon (*Lowman*)

6 Wedge shaped resection and arthrodesis of the subastragalar joint (Zadek)

7 Wedge osteotomy of the inferior medial surface and neck of the astragalus (Clark)

8. Partial obliteration of the sinus tarsi by a bone graft (Chambers)

Manual correction of pes planus deformity, with or without division of the peroneal tendons and lengthening of the achillis tendon, is adaptable only for use in children and adolescents with a rigid foot and many adhesions between the small joints. In children organic changes which cause rigidity are uncommon

Technic (Robert Jones) —The foot is placed over a wedge shaped block of wood which has been well padded at the upper edge The block should be of a size commensurate with the age of the patient one with angles of 45 degrees is most suitable. The patient is turned on his side the center of the medial aspect of the foot is placed against the padded angle of the block, and repeated force is exerted on the heel and forefoot Often, ligaments and adhesions may be heard tearing as the arch is elevated and the forefoot adducted over the wedge.

In our experience this procedure has been so manifestly unsatisfactory that it has been practically abandoned Almost without exception, particularly in the spastic type of flat feet the deformity recurs and there is even more stiffness and rigidity than prior to the manipulation One had best continue with conservative treatment or resort to appropriate surgery

After Treatment.—With the arch elevated and the foot well adducted a cast is applied from the toes to just below the knee, a felt pad being first placed along the anterior portion of the outer border of the foot to prevent pressure and pain. The cast should remain intact for six weeks. Plaster models are then made for a steel arch support of the Whitman or any other type which will maintain the corrected position A suitable shoe is fitted and foot exercises and physical therapy are begun. At the end of six months, the steel support is replaced by a flexible leather-cork support with or without elevation of the heel on the inner side Exercises are practiced rigidly for one year while the corrective shoes are worn for a similar period.

Pain is generally relieved by this procedure, although the cosmetic result leaves much to be desired.

Kidner described an operation for a certain type of pes planus wherein an accessory scaphoid or prehallux appears as a supernumerary bone on the medial surface of the scaphoid Usually the tibialis posticus tendon is attached to the prehallux, passing across the medial aspect of the scaphoid rather than beneath it thus, the normal suspensory support to the longitudinal arch is lost. Further adduction of the foot is obstructed by the close approach of the prehallux to the internal malleolus. The prehallux and altered insertion of the tibialis posticus tendon are demonstrated by roentgenograms of the foot and by physical examination These abnormalities are corrected by excision of the prehallux and transplantation of the tendon attachment to a point well under the scaphoid

Technic (Kidner) —The incision is begun in front of the internal malleolus and extended anteriorly to the base of the first metatarsal bone with a slight curve toward the sole of the foot. The fascia and periosteum are incised longi

tudinally and the tendon is dissected free its attachments to the prehallux and cuneiform bones being carefully conserved. A dorsal and a ventral flap are formed by dissection of both the fascia and the periosteum from the superior and inferior surfaces of the scaphoid and anterior portion of the astragalus the ventral flap is dissected loose for at least one inch on the inferior surface of the scaphoid and head and neck of the astragalus. With a thin osteotome, the tibial tendon is freed from the inner tip of the scaphoid, together with a small fragment of the bone. The medial fibers are then detached from the medial surface of the cuneiform bone while the inferior fibers remain undisturbed Thus, the distal insertion of the tendon beneath the longitudinal arch is preserved and a straight line of pull is insured when the tendon is transposed The entire tendon is then transplanted inferiorly and laterally into a groove on the lower surface of the scaphoid Usually this groove is

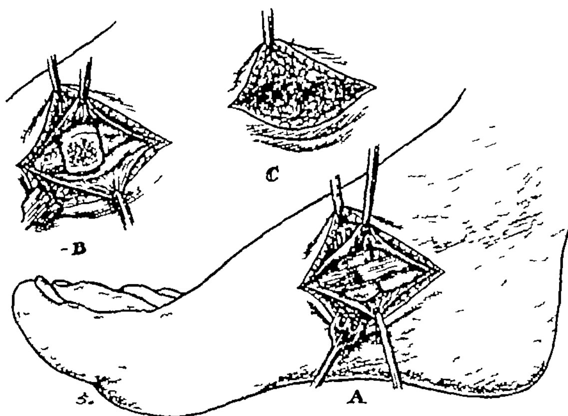


Fig 1054.—Kidner operation for prehallux. *A* Incision on medial side of foot. Dorsal and ventral flaps formed by fascia and periosteum, exposing prehallux and attached posterior tibial tendon. *B*, Tibial tendon freed from scaphoid with small fragment of bone transferred beneath longitudinal arch and held in place with chromic catgut suture through ventral flap of fascia and periostum. *C* Closure of dorsal and ventral flaps over raw surface of scaphoid bone.

present if not, one is created with an osteotome. The prehallux and the medial surface of the scaphoid are next removed flush with the astragalus and cuneiform bones. If the inferior soft tissue flap is strong and firm two chromic catgut sutures are passed through the flap as far laterally as possible from below upward, thence through the tendon and down again through the flap to be tied in the sole of the foot otherwise, the tendon is fastened in its new bed by chromic catgut sutures passed through two drill holes from above downward through the middle of the scaphoid bone. During this procedure, the tendon should be held under slight tension and the foot in moderate cavus and supination. The upper and lower flaps are sutured together over the raw surface of the scaphoid, burying the tendon in its new bed.

After Treatment —See p 1519

Miller and Hoke have described ingenious operations for pes planus which entail fusion of several minor tarsal joints. By either method, a satisfactory cosmetic effect is secured without severely impairing the range of motion of the foot We have employed the Miller technic, with good results in the majority of cases.

Technic (Miller) —An incision is made along the inner side of the foot from the os calcis forward over the bodies of the scaphoid and internal cuneiform bones, ending at the base of the first metatarsal bone This brings into view the calcaneoscaphoid ligament and the insertions of the posterior and anterior tibial tendons. After dissection of the subcutaneous fascia, a thin slab of bone from the side of the scaphoid and internal cuneiform bones, including the fanned-out insertion of the calcaneoscaphoid ligament and

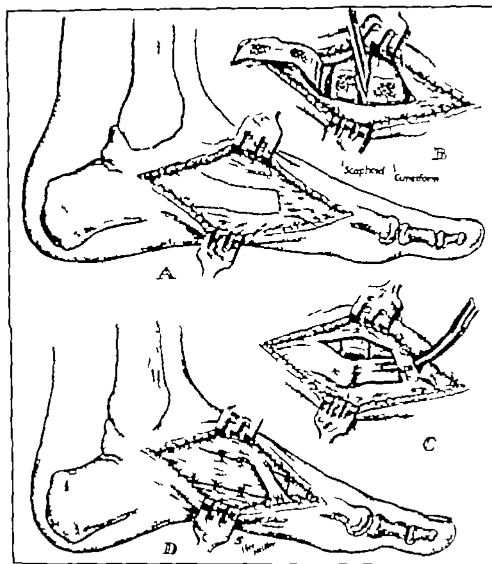


Fig. 1636.—Miller operation for pes planus *A* Exposure on medial side of foot. Flap of fascia outlined and dissected free with small segment of bone from scaphoid and internal cuneiform bones. *B* Cartilage excised from articulations of scaphoid and internal cuneiform bones and base of first metatarsal and internal cuneiform bones. Insertion of tibialis anticus tendon is not disturbed. Arch restored by rotating and adducting forefoot. *C* Small segment of bone lifted with periosteum from side of first metatarsal fascial sling and small segment of bone brought forward beneath tibialis anticus, to be stitched under tension to side of first metatarsal bone. Segments of bone on flap should lie across joint spaces to act as grafts. *D* Fascia sutured in place, maintaining a normal arch line. (Redrawn from Miller O. L.: J Bone & Joint Surg. 9: 84, 1927)

posterior tibial tendon is raised with a chisel or osteotome The joints between the astragalus and scaphoid scaphoid and internal cuneiform, and internal cuneiform and base of the first metatarsal bones are thus exposed. The lesser articular ligaments are lifted upward and downward subperiosteally and conserved to be reapplied over the area of fusion The cartilage between the scaphoid and internal cuneiform bones, and internal cuneiform and head of the first metatarsal bones is excised If the head and neck of the astragalus are abnormally long and the point of the scaphoid is hypertrophied on its inner aspect the neck of the astragalus is shortened by taking out a section with an osteotome The tendo achillis is then lengthened. When

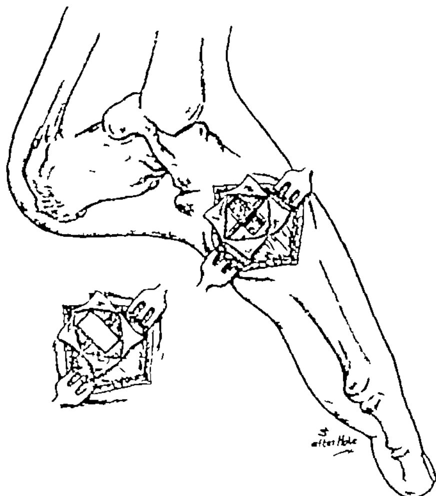


Fig. 1056—Operation of Hoke for pes planus. Tendo achillis lengthened (not shown in illustration) Medial incision exposing scaphocuneiform joint. Cartilaginous surfaces removed from scaphoid and middle and internal cuneiform bones. Arch restored by forcing anterior end of first metatarsal bone into equinus. Small rectangular segment of bone removed from across scaphocuneiform joint. Insert shows cortical graft of equal dimension countersunk int defect. (Redrawn from Hoke Michael J Bone & Joint Surg. 13: 772 1931)

the forefoot is adducted the first metatarsal bone rotates to a corrected position. The segment of bone holding the insertion of the calcaneoscaphoid ligament and a portion of the posterior tibial tendon is next pulled forward, passed beneath the anterior tibial tendon under tension, and sutured as a graft to the body of the internal cuneiform and base of the first metatarsal bone The insertion of the anterior tibial tendon is not disturbed.

We have found that even in extreme planus perfect correction of the longitudinal arch may be secured by supplementing this procedure with

resection of a wedge from the joints between the cuneiform and scaphoid bones and continuance of the osteotomy laterally through the cuboid, to permit adequate adduction and rotation of the forefoot

After Treatment.—A plaster cast is worn for a period of six weeks. Supervised weight bearing is begun immediately thereafter with the foot supported by a light metal arch in a corrective shoe Foot exercises and massage are also carried out for a short time

Following this procedure, the scaphoid and internal cuneiform bones and the base of the first metatarsal bone fuse in their corrected relations. The calcaneoscaphoid ligament and posterior tibial tendon being tightened on transplantation forward, form a substantial sling which holds the head of the astragalus in the normal weight bearing line of the foot.

The Hoke operation embodies fusion of the joints between the scaphoid and internal and middle cuneiform bones.

Technic (Hoke) —As the first step in the procedure, the tendo achillis is lengthened and the skin sutured (p 1021) A second incision is then made along the medial border of the foot, exposing the scaphocuneiform joint, and the cartilaginous articular surfaces are excised from the scaphoid and internal and middle cuneiform bones. The foot and anterior end of the first metatarsal bone are forced into equinus and so maintained while a rectangular block of bone is resected from the scaphoid and medial cuneiform bones across the joint. A segment of cortical bone of equal dimensions is removed from the tibia above and fitted into the area created by resection of this rectangular block, bridging the joint as an inlay tibial graft. Small fragments of bone are packed into the unfilled spaces, and periosteal flaps are closed over the graft

After Treatment.—The cast is applied in two sections, the first part encasing only the foot. With the foot and anterior end of the first metatarsal bone in equinus and the heel inverted a plaster reinforcement is applied being well molded under the scaphocuneiform joint After the plaster has dried the ankle is dorsiflexed to a 90 degree angle with the leg and immobilized by a boot cast. Two weeks postoperatively this cast is removed and the foot is further immobilized in an ordinary boot cast for a period of six weeks. Massage is then given for a few days, and walking is resumed with the aid of metal arch supports.

In our opinion the technics of Lowman Zadek and Clark, described further are suitable only for exaggerated cases of pes planus of long standing with arthritic changes and rigidity of the joints. Undoubtedly correction may be excellent by arthrodesis of one or more of the principal tarsal joints the elimination of lateral motion in the foot, however is a serious disadvantage. Under only exceptional circumstances should these operations be performed on young individuals.

Technic (Lowman).—Beginning below the internal malleolus, the incision is carried distally with a slight dorsal convexity to a point above the navicular thence continued distally and toward the plantar surface to a point on the medial side of the base of the first metatarsal bone. The fascia is incised in a straight line bringing into view the tip of the navicular and the edge of the calcaneonavicular ligament The talonavicular ligament is divided in line with the joint, and the medial portion of the navicular is exposed subperiosteally Through a separate incision, the tendo achillis is then lengthened (p 1021) allowing the posterior portion of the calcaneus to be lowered. A wedge, its base on the medial and plantar aspects, is resected from the talonavicu

lar joint, a sufficient amount of bone being removed to permit adduction and depression of the forefoot for the formation of a satisfactory arch. The peroneal tendons may be divided if necessary through a separate small incision just below the external malleolus. The anterior tibial tendon is next rerouted through the site of the resected joint, its insertion remaining intact, this places the principal pull of the tendon directly over the apex of the arch. If desirable the tendon may be held in place between the resected ends of the talus and navicular by a suture inserted through the calcaneonavicular ligament. The edges of the talonavicular ligament are then overlapped and sutured thus maintaining the corrected position

In some cases, the peroneus longus tendon is brought through the sheath of the anterior tibial tendon and sutured to the talonavicular ligament.

After Treatment.—With the foot in the corrected position and the knee in slight flexion a plaster cast is applied from just above the knee to the toes. At the end of four weeks this cast is replaced by a walking cast which does not include the knee. Weight bearing is permitted after eight weeks. Three months postoperatively the cast is discarded and shoes containing a metal arch support are fitted and worn for six months to one year

Zadek has recently attacked the problem from an entirely different mechanical point of view correction of the outward angulation of the heel by arthrodesis of the subastragalar joint and removal of an oblique wedge. When fusion takes place the heel is tilted inward, correcting the eversion of the os calcis. Zadek claims that this method also restores the longitudinal arch

Technic (Zadek).—The incision is begun posterior to the astragaloscaphoid joint and passed proximally along the posterior tibial tendon. The latter is removed from its sheath and retracted downward The soft structures are stripped subperiosteally to the subastragalar joint injury to the posterior tibial nerve and the vessels being avoided by dissection close to the bone. A wedge shaped section of bone is removed from the subastragalar joint the base of the wedge should be toward the medial aspect of the joint and of sufficient width to permit correction of the valgus of the heel.

After Treatment.—A cast which holds the foot and heel well inverted is worn for four weeks and then replaced by a walking cast. Three months postoperatively the cast is removed physical therapy is begun and walking resumed with the aid of Whitman steel arches.

Following a technic similar in principle to that of Zadek, Clark corrects the eversion of the os calcis by resection of the cartilage and bone from the inferior medial surface of the astragalus. The abduction of the forefoot is corrected by resection of the neck of the astragalus.

Technic (Clark).—The incision is carried from the external malleolus to a point over the middle cuneiform bone The soft tissue is stripped subperiosteally exposing the head and neck of the talus, and the head is removed temporarily following osteotomy through the neck. A wedge of bone of sufficient width to permit correction of the valgus of the heel is then excised from the medial side of the inferior surface of the talus. The cartilage on the superior surface of the calcaneus is not disturbed A wedge is also removed from the medial side of the resected neck and head and this portion of the talus is replaced.

After Treatment.—By means of a plaster cast the foot is immobilized in extreme supination and adduction for a period of six weeks. Walking is then permitted the heel of the shoe being elevated on the inner side

Aseptic necrosis of the head of the talus may develop following this operation, and some degree of pain or ankylosis may possibly ensue in the subastragalar joint Clark states, however that there is no subsequent ankylosis or pain

The Chambers operation is based upon an anatomical observation of flat feet and later proved clinically namely that when a flat foot is hyper abducted the body of the astragalus slides forward and downward on the posterior calcaneal facet until its anterior edge makes contact with the bottom of the sinus tarsi Abduction of the foot beneath the talus can be checked if the sinus tarsi is obliterated by filling it with grafted bone however, abduction will remain undisturbed The extent to which abduction will be limited will depend upon the degree to which the depth of the sinus is reduced Thus the curtailment of excess abduction by means of a bone grafting procedure of this nature provides a means of controlling the postural collapse of the flexible flat foot without interfering with any of its movements. We have had no experience with this procedure

Technic (Chambers)—With the foot held in an adducted position, an incision is made over the lateral aspect of the talus and subtalar joints. By raising the extensor brevis digitorum from its attachment to the calcaneus, together with the fibrous areolar tissue filling the sinus tarsi, the anterior surface of the talus and sinus tarsi are brought into view The portion of the sinus tarsi immediately in front of the forward tip of the posterior calcaneal facet is cleared but the outer fibers of the interosseous ligament are not disturbed.

The foot is brought to a neutral position, and the area of the posterior calcaneal facet remaining uncovered by the talus is estimated. A bone flap is next raised from the floor of the sinus tarsi extending ¼ to ⅜ inch in front of the joint surface as well as that portion of the joint surface left uncovered when the foot is placed in a neutral position. The foot is held adducted when cutting the bone flap

After the flap is pried up the desired position is permanently maintained by a small bone graft beneath it. This graft may be taken from the tibia or as the author prefers, from the calcaneus just forward of the site from which the primary flap was raised. The use of the bone chips enable the operator to elevate the primary bone flap to the exact height desired and support it in this position. Only the excess of abduction is eliminated a few degrees of abduction must remain.

The wound is closed after the extensor brevis digitorum is anchored to the exposed fibers of the interosseous ligament, and its fascial covering is carefully repaired. The tendo achillis is routinely lengthened by tenotomy

After Treatment.—A long leg plaster cast is applied the foot being held in a neutral position and at a right angle to the leg Any deviation of this position should tend preferably toward a little abduction. The cast is changed in twelve to fourteen days to remove sutures and to make any necessary change in position Immobilization is continued for ten weeks. Subsequently the feet are supported in Whitman plates or the combined use of a simple arch support and an ankle brace with an inner T-strap Active and passive adduction is now instituted but abduction is avoided.

HALLUX VALGUS (BUNION)

In hallux valgus, or bunion, the great toe is deflected to the outer side of the foot causing an undue medial protuberance of the head of the first metatarsal bone. A bursa is always present. Both great toes are generally affected Hypertrophic arthritis or osteoarthritis of the metacarpophalangeal joint is often a complication, the affection being either local or a part of a generalized arthritis. Pain may be present in either or both joints.

A depression of the anterior arch, manifested by the prominence of the heads of the metatarsal bones and callous formation on the sole of the foot, is often associated with hallux valgus. There is usually some degree of splaying of the forefoot as indicated by separation of the metatarsal bones, especially between the first and second An operation solely for hallux valgus, therefore does not entirely relieve the disability

Surgery is indicated for relief of symptoms alone and should not be undertaken merely for cosmetic purposes. The treatment should include the following measures

1 Correction of the valgus deformity at the metatarsophalangeal joint.

2. Removal of the exostosis or excess bone on the medial aspect of the first metatarsal head and in some cases, the adventitious bursa as well. Practically all operations have this feature

3 Correction, if possible, of the metatarsus primus varus deformity (widening of the space between the first and second metatarsal bones as a result of medial angulation of the first metatarsal bone at its articulation with the cuneiform bones) which is frequently associated with hallux valgus.

4 Postoperative treatment of the depression of the anterior arch and associated metatarsalgia

Three types of operation have been recommended for correction of hallux valgus (1) plastic procedures, (2) excisions of bone, and (3) measures to correct the metatarsus primus varus combined with either plastic procedures or excisions of bone

Plastic procedures, wherein surgery is limited principally to the soft structures, are best exemplified by the McBride operation. The insertion of the adductor hallucis tendon is detached from the first phalanx of the great toe and utilized to maintain the head of the first metatarsal bone against the second.

Excisions include (1) resection of sufficient bone to shorten the osseous structures, relax the contracted soft tissues, and place the joint in a satisfactory position, and (2) removal of the portion of the joint surface involved in arthritic changes. Either the head of the first metatarsal bone may be remodeled or partially resected as in the Mayo operation, or the proximal portion of the first phalanx may be removed as in the Keller operation. Other procedures based upon the resection of bone are those of Porter Fowler and Girdlestone

In addition to correction of the deformity of the toe the operation of Lapidus aims at correction of the metatarsus primus varus at the first metatarsocuneiform joint and maintenance of this correction by fusion.

In any operation on the first toe or metatarsophalangeal joint flexion should be unimpaired extension of this toe is severely disabling As a rule, the methods in current use are more conservative than those formerly employed. In the presence of only moderate hallux valgus deformity par

ticularly in young individuals we have employed the McBride operation with gratifying success. We also use this procedure in practically all cases where in surgery is limited principally to the soft structures. The Keller operation is employed in practically all cases in which the excision of bone is required to shorten the osseous structures, relax the contracted soft tissues and place the joint in a satisfactory position, this technic is particularly applicable to hallux rigidus. The Mayo procedure is reserved for elderly individuals with generalized arthritic flat feet presenting a severe valgus deformity of the first metatarsophalangeal joint. In this situation the toe has already lost its function and partial removal of the head will not further impair the gait.

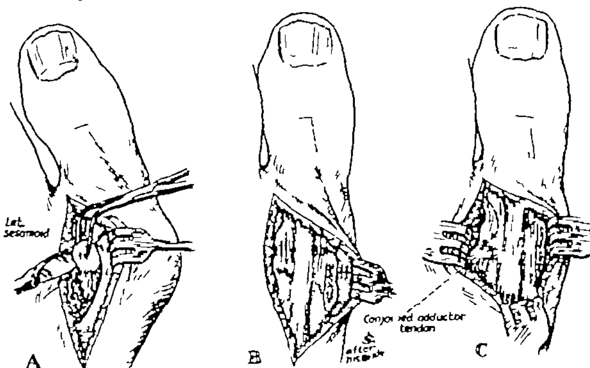


Fig. 1047.—McBride bunion operation. A Technic of removal of lateral sesamoid bone. B Hypertrophied portion of metatarsal head excised capsule plicated to maintain toe in normal alignment. C Conjoined adductor tendon detached from phalanx and inserted into metatarsal head. (Redrawn from McBride, E. D J. A. M. A. 105: 1164 1935.)

Technic (McBride).—The incision is begun just proximal to the interphalangeal joint of the great toe and extended along the lateral border of the extensor hallucis longus tendon to a point one inch proximal to the metatarsophalangeal joint. (We use two incisions instead of one in performing this operation besides the original incision which can be somewhat shortened proximally a curved incision its convexity toward the dorsum of the foot, is made for the removal of the exostosis. This second incision facilitates the removal of the exostosis, and obviates the trauma to the skin and soft parts, which is incident to the retraction necessary when only the one incision is used.) The dissection is carried deep on the lateral side of the joint, the adductor hallucis tendon is isolated and detached at its insertion to the base of the first phalanx, and the capsule of the joint opened on the lateral side. The lateral sesamoid bone is next dissected out of its bed in the adductor and flexor hallucis brevis tendons. Its removal is tedious and care should be taken not to damage the flexor hallucis longus tendon. The sesamoid is freed at its distal and proximal edges with a sharp scalpel it is then grasped with a towel clip or small hook and pulled dorsally and upward as dissection is



Fig. 1058.—Hallux varus deformity following McBride bunion operation.

Fig. 1059.—Before and after McBride operation for hallux valgus. Lateral sesamoid bone was not removed.



Fig. 1058.—Hallux varus deformity following McBride bunion operation.

Fig. 1059.—Before and after McBride operation for hallux valgus. Lateral sesamoid bone was not removed.

made medially beneath it. The medial skin flap is raised and retracted medially together with the extensor hallucis tendon thereby exposing the exostosis on the medial side of the metatarsal head. The exostosis is removed with an osteotome. The distal end of the first metatarsal is then approximated to the second metatarsal bone. The adductor hallucis tendon is attached to the lateral side of the first metatarsal at its neck by means of a suture in the soft tissue and periosteum at that point. (Note: The soft tissue in this region is fragile and frequently fixation of the tendon is inadequate; in this event a hole is drilled through the neck of the first metatarsal and the tendon is sutured in place with chromic cat gut.) The medial capsule is sutured and shortened to maintain overcorrection of the toe.

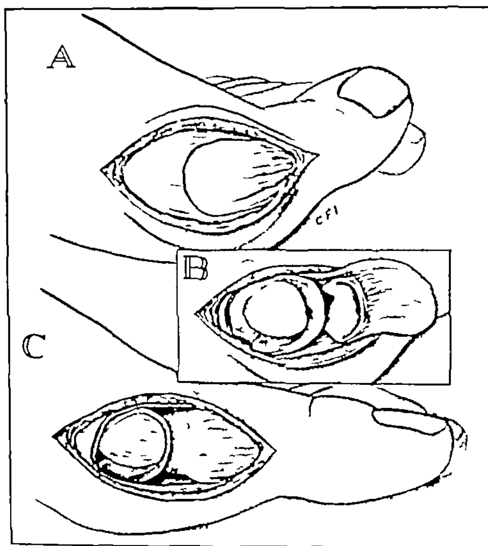


Fig 1040.—Mayo bunion operation. *A*, Line of incision. Flap of fascia and bursa outlined, with base attached to proximal phalanx. *B*, Redundant portion of bone removed from medial side of head of first metatarsal bone, and articular surface remodeled. *C*, Flap of tissue interposed as a new lining for the joint and fixed by two sutures through lateral capsule. Weight-bearing surface of metatarsal head is not disturbed.

After Treatment.—The foot is placed in a plaster slipper which holds the toe in the corrected position. After two weeks, motion is encouraged and weight bearing is resumed.

In two of McBride's cases and in one of ours, an undesirable deformity from overaction of the unopposed abductor muscle followed this procedure.

This complication may possibly be overcome by tenotomy of the abductor muscle and plication of the lateral capsule

The Mayo operation is essentially a semiarthroplasty of the first metatarsophalangeal joint The sesamoid bones are left intact. The technic is based on that of Heuter wherein the head of the first metatarsal bone is excised

Technic (Mayo)—A curved incision, its convexity toward the dorsum of the foot, is made over the inner side of the metatarsophalangeal joint and the skin is separated from the underlying bursa A U-shaped incision is now made through the bursa to form a flap with its attachment on the first phalanx. The inner surface of the flap consists of synovial membrane and is continuous with the interior of the joint. The exostosis or bony hypertrophy on the inner side of the metatarsal head is excised from before backward



Fig. 1081.—Plaster cast to maintain corrected position after bunion operation. Later, cast is bivalved, straps and buckles are applied and cast used as a night splint for several weeks postoperatively

flush with the shaft of the metatarsal bone The head of the metatarsal bone is then removed with bone-cutting forceps. (This procedure can be modified as follows Only about one fourth inch of the entire articular surface is excised from the head of the metatarsal bone The head is then remodeled to form a smooth convex surface which conforms to the curve of the articular surface of the phalanx. By this modification practically the entire weight bearing area of the metatarsal head is preserved.) The bursal flap is then turned into the joint space and sutured to the lateral capsule of the joint by one or two catgut stitches. Thus, the bursa is utilized to secure and maintain a movable joint.

After Treatment.—A plaster cast constructed on the lines of a slipper is applied to the foot, holding the toe in slight flexion and abduction. The foot is elevated for forty-eight hours to reduce the postoperative reaction to a

minimum At the end of ten days or two weeks straps and buckles are placed on the splint to facilitate its removal for passive and active exercises of the toe Weight bearing is resumed at this time with the aid of an orthopedic

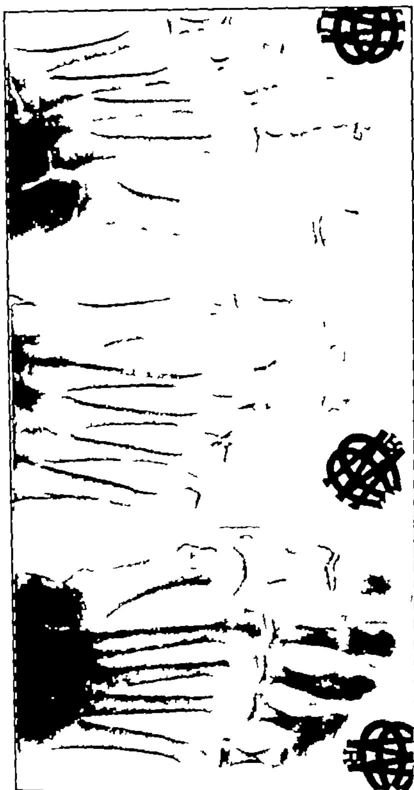


Fig 1062—End results of Mayo bunion procedure Preoperative roentgenograms showed from moderate to severe hallux valgus deformity in these three patients.

shoe and a leather-cork arch support with a metatarsal pad Exercises with the toe board should be carried out for at least three months. The bunion splint is worn at night for several months. The support and shoes usually are worn for at least six months.

Technic (Keller).—A curved incision, its convexity toward the dorsum of the foot, is made along the medial aspect of the metatarsophalangeal joint. The capsular ligament and periosteum at the base of the phalanx are incised and retracted, exposing the articular surfaces. The phalanx is then disarticulated. With a *Gigli* saw a portion of the base of the phalanx is removed, allowing the distal portion to be placed in an overcorrected position medially without impinging upon the head of the first metatarsal bone. The exostosis is removed in a plane extending obliquely upward and outward, in order to preserve the weight-bearing surface of the metatarsal head. The remains of the periosteum, capsular ligament, and other adjacent soft tissues are brought over the extremity of the resected phalanx by a figure-of-eight suture. A few figure-of-eight sutures bring the subcutaneous structures into apposition.

After Treatment.—See p 1530

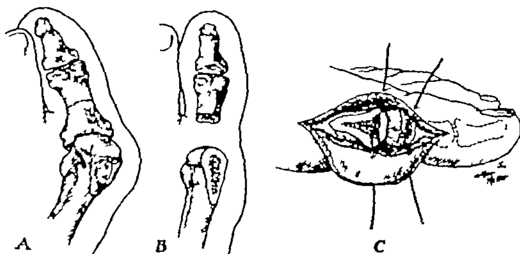


Fig. 1043.—Keller operation for hallux valgus. *A*, Dotted line indicates bone resected from proximal portion of phalanx and redundant portion of head of first metatarsal bone. *B*, Bone resected. *C*, Figure-of-eight suture draw remains of periosteum, capsular ligament, and other adjacent soft tissues over extremity of resected phalanx. (Redrawn from Keller W L: New York M. J 95: 696, 1912.)

Technic (Porter).—A crescent shaped incision two inches long with its convexity downward, is made just below the edge of the callus which covers the enlarged head of the metatarsal bone. The capsule is incised in the same direction the full length of the skin incision and together with the periosteum is dissected free from the bone and retracted. Two thirds to three-fourths of the head of the metatarsal bone is removed at such an angle as to include all the enlarged tuberosity though without shortening the bone. All the rough surfaces are smoothed. The toe is then pulled strongly inward, and the extensor hallucis longus tendon, which is thus brought into prominence, is divided subcutaneously at the level of the joint. With slight pressure the toe can be held straight. Occasionally the capsule on the outer side of the toe must be divided with a tenotome. While the toe is held in the corrected position, a mattress suture of 20- to 40-day catgut is placed in the medial capsule in a longitudinal direction approximating the distal and proximal angles of the capsular incision. If the proper amount of bone has been removed and the tendon divided, the toe will remain straight.

After Treatment.—See p 1530

The Lapidus procedure is based on the same principle as operations described by J K Young Truslow and Kleinberg An excellent mechanical correction is obtained weight bearing however, is materially delayed following operation

Technic (Lapidus) —An incision two inches in length is made on the dorsomedial aspect of the foot in line with the joint between the first and second cuneiform bones, its midpoint at the cuneiform metatarsal joint The articulation of the first cuneiform with the first metatarsal bone and the base of the adjacent second metatarsal bone is exposed subperiosteally The dorsalis pedis artery and its branches should be carefully avoided The cartilage is excised from the first cuneiform metatarsal joint and sufficient bone is removed from the lateral side of the joint to permit correction of the varus of the first metatarsal bone The medial side of the first cuneiform metatarsal joint should not be resected as shortening produces a disturbance of the normal dynamics of the foot moreover a wide gap is not conducive to fusion. The adjacent medial aspect of the base of the second metatarsal bone is also freshened All surfaces are then approximated and a few bone chips are inserted between the first and second metatarsal bones just distal to their bases. This procedure serves to promote fusion between the first cuneiform and the bases of the first and second metatarsal bones.

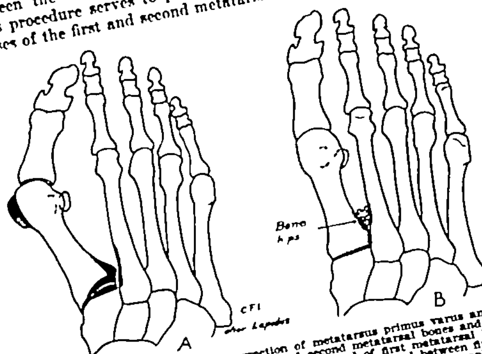


Fig. 1664.—Lapidus procedure for correction of metatarsus primus varus and hallux valgus deformity A Shaded area at base of first and second metatarsal bones and distal end of medial cuneiform bone resected. Redundant portion of head of first metatarsal bone removed. B Metatarsal bone swung into normal alignment. Bone chips placed between first and second metatarsal bone to insure fusion in this position. Valgus deformity of metatarsophalangeal joint corrected by division of adductor hallucis tendon and plication of medial capsule. Abductor hallucis tendon attached to medial flap of joint capsule to provide active force in maintaining corrected position. (Redrawn from Lapidus, P W Surg. Gynec. Obst. 58: 183, 1934.)

Through a second incision on the dorsomedial aspect of the metatarsophalangeal joint the exostosis is resected the lateral side of the joint capsule incised and the adductor hallucis tendon divided A tongue-shaped flap with its base attached to the proximal phalanx is made over the medial part of the joint capsule and the toe is brought into an overcorrected position A mattress suture of heavy chromic catgut is inserted on the medial side of the metatarsophalangeal joint the first stitch being taken through the plantar and distal part of the capsule anterior and medial to the inner sesamoid bone

The needle is then brought through the dorsal proximal portion of the joint capsule and the deep fascia. Thus, the suture crosses the medial side of the metatarsophalangeal joint obliquely from its plantar and distal surface toward the dorsal and proximal aspect. The tongue-shaped flap of capsule is now resutured while the toe is held in adduction. The abductor hallucis tendon is reattached to the medial flap of the joint capsule to provide active force in maintaining the corrected position

After Treatment.—Approximation of the metatarsal bones is maintained by means of a flannel bandage After the postoperative reaction subsides, the foot, exclusive of the great toe, is placed in a plaster cast Walking with crutches is allowed after two weeks, weight being borne on the heels. Four weeks postoperatively a shoe containing an arch support is fitted and at this time physical therapy is instituted. Lapidus states that the average patient may resume his occupation after six to eight weeks.

The end results of bunion operations as a whole are satisfactory Occasionally however following operation by any technic, the outcome may be disappointing and the patient may become a walking advertisement of the failure of the procedure. In the opinion of the patient a bunion may be a simple deformity which requires only a minor operation a poor result, therefore, may seem exaggerated in comparison to a result equally poor following operation for an extreme disability

DIGITUS MINIMIS VARUS (BUNIONETTES)

Arthritis, or prolonged irritation from ill fitting shoes, may give rise to an exostosis with an overlying chronically inflamed bursa at the base or head of the fifth metatarsal bone. If conservative measures do not afford relief, the excess bone and the bursa are excised.

Technic.—*A one-inch longitudinal incision is made over the bony prominence.* The bursa is dissected out in toto if possible and the exostosis is removed with rongeurs or a small osteotome

After Treatment.—Weight bearing may be resumed after ten days. The side of the shoe should be cut out over the operative area

HALLUX VARUS

Hallux varus, in contrast to hallux valgus, is a medial angulation of the great toe at the metatarsophalangeal joint. The deformity usually is of congenital origin (p 1563) and in this event may be associated with an equinovarus of the foot however trauma, infection muscle imbalance from paralysis of the adductor hallucis tendon or a bunion operation in which the outer capsule and insertion of the adductor hallucis tendon are severed may also be responsible for hallux varus. The condition must not be confused with metatarsus primus varus, *which is a widening of the angle between the first and second metatarsals* without a primary deformity at the metatarsophalangeal joint. When present to a severe degree, operative treatment is warranted.

Technic.—A linear incision two inches in length is made over the outer superior aspect of the joint, as *for the McBride bunion operation, and dissection* is continued down to the joint. The capsule is incised transversely on the outer and superior aspects and complete exposure is obtained by displacement of the phalanx medially thus increasing the deformity The capsule on the inner aspect of the metatarsophalangeal joint is then incised and the ab-

ductor hallucis longus tendon severed To fix the toe in the corrected position the lateral portion of the capsule is plicated with a No 1 chromic catgut mattress stitch If the tissue is friable the suture may be passed through a hole drilled in the metatarsal bone

After Treatment.—The great toe is flexed and held against the second toe and so maintained by a simple metal splint The treatment thereafter is carried out as following the bunion operation

MORTON S TOE—NEUROMA OF PLANTAR NERVE

Betts and McElvenny working independently, called attention to the true etiology of Morton s toe or anterior metatarsalgia namely a tumor of the most lateral branch of the medial plantar nerve The tumor is situated between the third and fourth toes at the level or proximal to the metatarsal

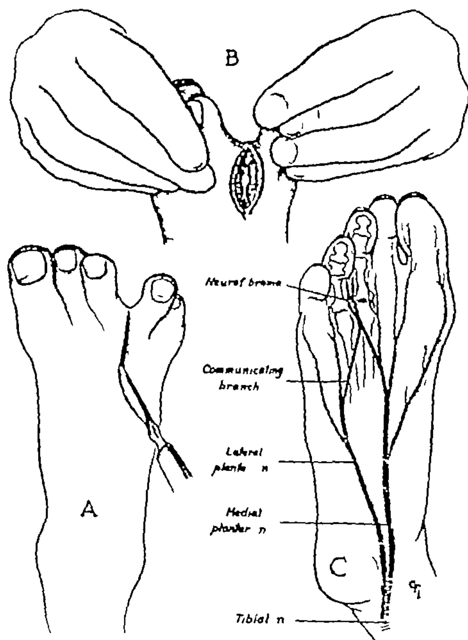


Fig. 1065.—McElvenny technic for neuroma of plantar nerve. A Line of skin incision. B Exposure of neuroma. C Details of anatomy of plantar nerve, and usual location of neurofibroma.

heads The condition is often refractory to conservative treatment results after excision of the tumor are so gratifying that we do not hesitate to recommend operation as soon as a diagnosis is made.

Technic (McElvenny) —A webb-splitting dorsal incision is made between the heads of the third and fourth metatarsal bones beginning one inch proximal to the webb and extending to the junction of the webb with the weight bearing skin of the sole of the foot. Dissection is carried down between the heads and necks of the metatarsal bone. The heads of the bones are retracted and the transverse ligament incised thereby providing adequate access to the floor of the incision After incision of the ligament, the tumor bulges up into the wound. Most commonly the nerve is enlarged and thickened from the distal bifurcation proximally towards its junction with a branch from the lateral plantar nerve. The tumor is completely excised.

After Treatment.—Special care is unnecessary weight-bearing may be instituted as soon as the wound is healed.

HALLUX RIGIDUS

In this condition there is no deformity but, rather restricted motion of the first metatarsophalangeal joint. Flexion is either practically impossible or extremely limited. Extension is always limited although to a less degree than flexion. The pathologic condition is a local osteoarthritis with proliferative changes in the joints these may be a part of a widespread hypertrophic arthritis, or may be limited to this joint as a result of trauma or infection. Because of the severe disability operation is always justified. Arthroplasty of the joint usually restores a range of motion sufficient for walking

Technic.—An incision is made along the medial aspect of the metatarsophalangeal joint. The subcutaneous structures are divided by a U-shaped incision, forming a flap with its attachment at the distal portion of the phalanx. The joint is dislocated and with bone-cutting forceps and a file, the base of the phalanx and head of the metatarsal bone are remodeled to form a concave and convex articular surface respectively The fascial flap is then inserted between the articular surfaces and so maintained by two catgut sutures through the lateral capsule. Occasionally the pedicle flap cannot be obtained from the inner aspect of the joint in this event, a free fascial transplant is excised from the opposite thigh and inserted into the joint as a double lining completely covering all articular surfaces.

After Treatment.—The postoperative care is similar to that described for the Mayo bunion operation. Physical therapy and passive and active exercises to the joint are especially important.

Resection of the base of the first phalanx as described by Keller for hallux valgus may also be employed for hallux rigidus.

HAMMERTOE

Hammertoe is a deformity of one or more of the toes characterized by flexion of the proximal interphalangeal joint and flexion or extension of the distal interphalangeal joint. In contrast to clawtoes, there is relatively little hyperextension of the metatarsophalangeal joints. The heads of the metatarsal bones may be depressed and prominent on the plantar surface of the foot, causing painful calluses beneath the heads of the metatarsal bones.

Callouses also develop over the dorsum of the flexed interphalangeal joint and on the end of the toe from constant irritation and pressure of the shoes The deformity may be of congenital or static origin, in the latter event arising from the use of ill fitting shoes and frequently being associated with a hallux valgus The second toe is most often affected

The simplest corrective procedure for the second third fourth and fifth toes is resection of the proximal interphalangeal joint, as originated by Sir Robert Jones, by which the bony structure of the toe is shortened sufficiently to relax the contracted soft tissues, permitting correction and preventing recurrence of the deformity

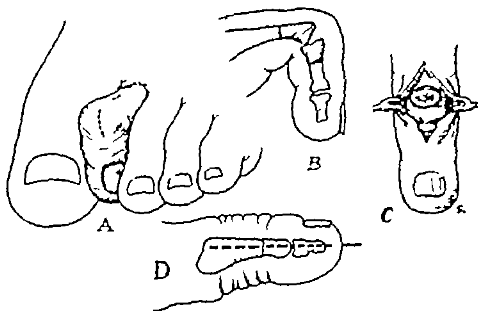


FIG. 1066 —Operation for hammertoe *A* Line of skin incision. *B* Shaded area indicates amount of bone resected from middle toe joint. *C* Sufficient bone removed to permit approximation of resected surfaces of joint and fusion in straight position. *D* Fixation with intramedullary wire

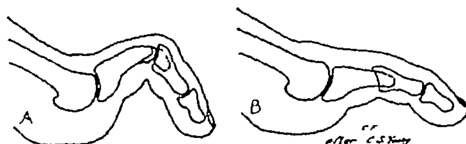


FIG. 1067 —Operation of Young for hammertoe *A* Distal end of proximal phalanx remodeled and *B* inserted into a hole of proper size and shape in base of middle phalanx. (Redrawn from Young, C. S. J Bone & Joint Surg 20: 715, 1938)

Technic.—A one-inch longitudinal incision is made over the interphalangeal joint. The extensor tendon is retracted, the interphalangeal joint exposed and, with a rongeur the base of the middle phalanx and the head of the proximal phalanx are removed A sufficient amount of bone is resected to correct the deformity and permit approximation of the osseous surfaces. Fixation is relatively simple to maintain by means of a Kirschner wire inserted in much the same manner as intramedullary fixation for a fracture. The point of the wire is drilled distally through the raw osseous surface of the proximal end of the middle phalanx, thence through the distal phalanx and out through the skin. The drill is then reversed the raw osseous surfaces of the proximal



Fig. 1068.—*A*, Freiberg's infraction of second metatarsal head, treated by resection. Toe amputated elsewhere. Example of poor mechanical result. *B*, To improve mechanics of foot, remainder of second metatarsal bone removed, and bases of third and fourth shifted toward medial side of foot after osteotomy. *C*, Valgus deformity of great toe still present, despite metatarsal reconstruction. Possibly Lapidus bunion operation might improve mechanical status.

and middle phalanges apposed and the intramedullary wire drilled proximally to transfix the joint and enter the intramedullary canal of the proximal phalanx The excess length of the wire is snipped off with a wire-cutter leaving one fourth inch of the wire protruding through the skin The joint is allowed to fuse in a straight position

In hammertoe deformity of the fifth toe no attempt is made to fuse the phalangeal joints correction is secured by removal of the middle phalanx or as much of the bone as is necessary

After Treatment.—The end of the wire is sealed off with a collodion dressing If additional immobilization is required the toe can be strapped with adhesive tape to the adjacent toe The wire is left intact for a period of three to four weeks and subsequently removed Weight bearing is not allowed until the wire has been removed

Young s procedure varies slightly from the measures usually employed

Technic (Young C S)—After proper exposure the distal extremity of the proximal phalanx is reshaped to resemble a truncated cone a portion of the dorsal cortex being left intact to maintain the strength of the bone With a drill and small gouge a hole of the proper size and shape to receive this reconstructed end of the first phalanx is created in the proximal portion of the middle phalanx and the ends of the two bones are fitted together

(Also see Clawtoes p 1290)

INFRACTION OF THE METATARSAL HEADS (FREIBERG'S DISEASE—KÖHLER S DISEASE)

This condition is characterized by degenerative changes in the heads of the metatarsal bones. In the majority of cases the second metatarsal is affected Clinically the disease may simulate metatarsalgia. Roentgenograms reveal pronounced irregularity of the articular surfaces of the metatarsophalangeal joint with broadening of the metatarsal head and thickening of the distal half of the shaft Loose bodies may be observed in the joint If symptoms persist after a reasonable trial of conservative treatment excision of the head of the diseased bone (p 883) may be necessary Because of removal of the head symptoms of varying severity may persist after operation.

INGROWN TOENAILS

This affection is practically limited to the great toe. The underlying cause is not an abnormal growth of the nail but rather a superfluous growth of soft tissue at the end of the nail from improper trimming of the nail or pressure of ill fitting shoes. Frequently a fungus infection or suppuration may produce chronic inflammatory changes of the soft tissue adjacent to the nail. Prior to operation all inflammation must be cleared up by means of hot packs or Dakin s solution

Technic (Heifetz)—An incision three-eighths inch long is made in the eponychium so as to include one third of the nail on the affected side Skin flaps are dissected up to expose the nail root. The nail is incised longitudinally from the distal end to the root, elevated with a small scapula and the involved portion, or approximately one third is removed with scissors. The matrix is next curetted out entirely this is the most important step in the procedure as the nail will be partially re-formed if any of the matrix remains To in

sure complete destruction of the matrix, the wound is thoroughly swabbed with phenol or silver nitrate, then neutralized with alcohol The hypertrophied soft tissue and nail bed are not disturbed

After Treatment.—The raw area is covered with several layers of vaseline gauze and a thick pressure bandage of plain gauze is applied. When the post operative reaction has subsided, the patient is allowed to resume weight bearing in a shoe which has been cut out over the great toe.

If conservative measures have been followed by a recurring infected in growing toenail, a more radical approach should be utilized the entire nail is removed the defect being covered by a plastic soft tissue procedure.

Technic.—*Two parallel incisions three-eighths of an inch long* are made in the eponychium at the medial and lateral borders of the nail. The inter mediate skin flap is dissected back to expose the nail root. Subsequently the entire nail is excised along with the matrix, thereby completely exposing the distal two-thirds of the distal phalanx. Sufficient bone is resected to permit end to-end soft tissue closure viz. the soft tissue of the distal end of the toe is sutured to the raw edge of the eponychial flap The wrinkled lateral borders of the skin ordinarily smooth out in a few months. If preferred "darts" may be excised from the lateral skin margins to permit a more pleasing plastic closure

After Treatment.—See above

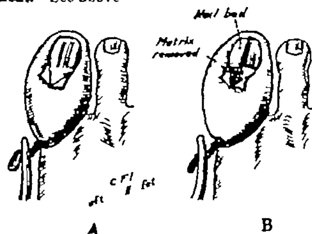


Fig. 1069.—Operation for ingrown toenail (Heifetz) Eponychium incised and medial third of nail removed. Matrix curetted to prevent re-formation of nail. (Redrawn from Heifetz, C. J Am. J Surg. 21: 298 1937)

CALCANEAL SPURS

Calcaneal spurs as seen in the roentgenogram are generally transverse ridges of bone. Usually these exostoses develop at the anterior edge of the medial portion of the calcaneal tuberosity Conservative measures, such as hot wet packs or a pad of sponge rubber in the heel of the shoe, are sufficient for relief of less severe symptoms. Occasionally however the pain and disability may warrant surgical intervention. All sources of infection should be eliminated.

Markellov and Ilin approach the os calcis through a horizontal horseshoe incision which encircles the heel in a manner similar to that of the old Kocher incision for exposure of the os calcis. The soft tissues on the plantar aspect are then dissected *forward and the spurs are removed* with a chisel. An in cision of such length is not necessary for removal of spurs. Usually medial and lateral incisions may be combined, if either does not alone afford adequate exposure.

in which the direct cause is obvious, as, for example, anterior poliomyelitis (p 1410) congenital anomalies of the spine, or empyema

The necessity for early and efficient treatment of patients with scoliosis arises from the extreme uncertainty of their future progress. In some cases the curvature may be arrested spontaneously in an early stage in others, the deformity may progress to such an extreme degree as to impair the general health of the patient Treatment should be directed not only toward correction of the deformity, if possible but toward maintenance of the correction as well.

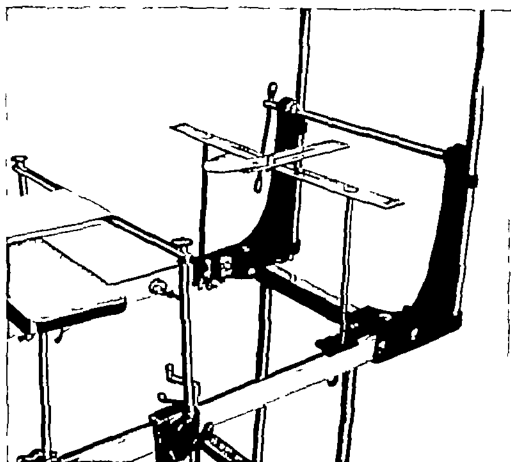


Fig 1071 —Attachments on Bell fracture table facilitate application of scoliosis jackets with chin and head support. Traction exerted by ratchet windlass at head of table. (Courtesy of Mr Gilbert Hyde Chick.)

Since the introduction of fusion operations on the spine, interest in the treatment of scoliosis has been greatly stimulated. Fusion of the affected region is a practical and efficient method of preventing an increase of the deformity and when combined with thorough preoperative and postoperative measures, in the majority of cases promises a far brighter outcome than can be anticipated by the use of conservative means alone. In every case, however the treatment must of course be adapted to the conditions present, with particular regard for the location degree and duration and to a lesser extent, the etiology of the deformity

In 1941 the Research Committee of the American Orthopedic Association made a report of an end result study of 425 cases of idiopathic scoliosis, studied

in various orthopedic centers in America Their conclusions were as follows (1) Practically none of the patients with scoliosis is cured if complete correction of the lateral deviation is a criterion, (2) In approximately 60 per cent of those treated by exercises the deformity increased, and in approximately 40 per cent it remained unchanged, (3) In the majority of cases correction without fusion resulted in complete loss of correction after support was discontinued, (4) Correction by the turnbuckle jacket and subsequent fusion yielded better results than other forms of treatment

Patients with scoliosis usually seek treatment because of the cosmetic effect of the deformity or backache the latter is somewhat unusual during the growth period For this reason an evaluation of the results of treatment must largely be based upon a comparison of the clinical appearance of the back at the end of treatment as compared with its appearance at the beginning of treatment Furthermore in order to evaluate the results fairly the progressive nature of the disease must be borne in mind Of 172 patients treated by Risser jacket and fusion 67 per cent were improved 22 per cent were unimproved, and 11 per cent grew worse Of 152 patients treated by exercises 5 per cent were improved 59 per cent were unimproved and 36 per cent grew worse



A B

Fig. 1072.—*A*, Hibbs-Risser Ferguson turnbuckle jacket cast. *B*, Correction of a mid dorsal curve completed Casts, with th exception of those for high cervicodorsal curves, usually extend to the knee on the side of the turnbuckle.

The above study further demonstrates that while the prognosis in idiopathic scoliosis is definitely guarded until the period of vertebral growth is past, the best therapeutic procedure available at present is correction by the Risser jacket followed by spinal fusion The subsequent discussion of treatment is based on the works of Hibbs Risser Ferguson, A. DeF Smith, Von Lackum Cobb Butte and Vom Saal

In addition to the clinical examination of the back, the original examination must include roentgenograms in the horizontal and standing positions. The leg lengths should be measured for comparison, and the height of the patient on standing and sitting should be determined These observations should be made periodically to demonstrate whether or not the condition is progressive and whether or not vertebral growth has ceased. The latter is most important, since it has been shown that the deformity does not progress after vertebral growth ceases.

Measurement of the Curves

The determination of the *angular degree of lateral deviation of the spine* is made as follows

The end vertebrae of a given curve are the ones at each end of the curve nearest to neutral and the least rotated. The apex vertebra is the one at the crest of the curve and most rotated. Vom Saal and Cobb determine the end vertebrae as follows Lines are projected parallel to and touching the upper border of each vertebra these lines become the radii of circles. When these radii cease being radii of one circle and form radii of a new circle another curve has been entered. It is apparent that each end vertebra is common to two adjacent curves.

To measure the amount of lateral angulation lines are erected perpendicular to the upper surfaces of the end vertebrae the angle projected by the insertion of these perpendiculars represents the angular degree of lateral deviation of this specific curve.

If the head is to be balanced above the pelvis, any angular deviation of the spine in one direction requires an opposite angular deviation when the erect position is assumed. This secondary deviation is compensation. Thus in a right primary dorsolumbar curve of 40 degrees there must be a compensatory left lateral deviation of the spine of 40 degrees for complete compensation. If there is less than 40 degrees to the left, the curve is decompensated while if there is more than 40 degrees the curve is overcompensated. Of more importance in this event, the curve is probably of the 'double primary'' variety These compensatory curves may occur either above or below the primary curve. Because of its great mobility and better mechanical efficiency however the lumbar area always provides a maximum degree of *compensation which is as low in the lumbar spine as possible.*

Identification of the Primary Curve

Compensatory curves of long standing tend to develop structural changes such as wedging and rotation of the vertebral bodies, and, hence are difficult to distinguish from primary curves. As a rule, the primary curve, or the one wherein the process is active, may be determined by the use of Ferguson's criteria

1 In the case of three curves the middle one is usually primary

2. The greater curve or the one toward which the trunk is shifted is the primary

3 The curve with the least flexibility and correctibility is the primary This rule is exemplified by the pelvic tilt test film, made in the anteroposterior plane with the patient sitting and with an elevation of three or four inches *beneath the buttock on the side of the lumbar or dorsolumbar convexity* This

film demonstrates the maximum ability of the patient to correct his lumbar curve spontaneously. If no correction is apparent the lumbar curve is primary; if compensatory it tends to correction.

Types of Curves and Factors in Treatment

Scoliosis Primary in the Dorsal Spine.—Because of the immobilizing action of the rib cage, the thoracic segment is relatively inflexible in the normal spine. In the scoliotic spine the mobility is further diminished because of the appearance of secondary changes in the ribs and other supporting structures. The Risser jacket, including the head helmet in high dorsal curves, is therefore



A B

Fig. 1072.—*A*, Model for leather lacer brace. *B*, Leather lacer brace with crutch arm to maintain corrected scoliosis.

relatively inefficient in correcting curves in this area and significant correction is frequently complicated by evidence of traction neuritis of the brachial plexus. Further, the curves are accompanied by rather severe deformity, such as convex side shoulder elevation, rib projection, and scapular prominence which are difficult to conceal by modern clothes. These deformities combined, particularly in girls, justify surgical intervention at an earlier date than those in the low dorsal area, though of course the fundamental indications for surgery must be considered in each case individually. In general, the higher the curve in the dorsal spine, the more severe the appearances of deformity, the more difficult the correction, and the earlier surgical intervention is indi-

cated. On the other hand, the lower the curve in the dorsal segment, the greater the attempt at compensation the less the deformity and the more easily is it corrected

Scoliosis Primary in the Lumbar Area.—Because of flexibility in this segment, considerable correction can be accomplished by the Risser jacket. Tilting of the fifth lumbar vertebra whether developmental or paralytic, exerts either an exaggerative or corrective influence on the primary lumbar curve, and must always be considered in treatment.

Indications for Surgery

In general a mild curve with good compensation and slight deformity is best treated by symmetrical postural exercises. The patient should be closely observed to determine the rate of progression of the disease. A progressive curve in a young and growing child is an indication for surgery

Risser has recently demonstrated a valuable point in the determination of the date of cessation of spinal growth in an individual case. He has found that, in the process of ossification the iliac apophysis is gradually calcified from before backward. Further he has observed that spinal growth continues until the apophyseal ossification center reaches the posterior superior iliac spine and turns medially and inferiorly toward the sacroiliac joint. When this 'turn' takes place no further spinal growth or increase in deformity may be expected.

The second indication for surgery is severe asymmetry and deformity of the trunk in adolescence regardless of whether or not spinal growth has ceased. Finally pain which cannot be controlled by conservative measures is an indication for fusion in older patients usually without previous attempts at correction

Determination of the Fusion Area.—In the management of scoliosis, the primary aim is restoration of body symmetry by centering the first dorsal spine above the sacrum with the pelvis and shoulders level. To this end, several roentgenograms must be studied to determine the location and degree of spontaneous correction which may be anticipated postoperatively and the amount of correction of the primary curve required prior to fusion. To determine the amount of spontaneous correction possible in the lumbar curve a sitting pelvic tilt film is made in the anteroposterior plane, with a three to four inch elevation of the buttock beneath the side of the lumbar convexity Second, to determine the possible correction of the upper compensatory curves, the patient is placed in the supine position, and a side bending film is made with the cervical and dorsal spine flexed toward the side of the upper dorsal convexity By addition of the angular values of the residual curves in these two areas, the total residual deviation of the spine in this direction may be determined Since complete compensation requires an equal residual lateral deviation of the spine in the opposite direction the primary curve may not be corrected to an angular value less than the total of the residual angulation in the compensatory curves.

Cobb has found that, if the sum of the opposite residual angulation is 0 degrees, complete correction of the primary curve is possible. On the other hand, if the sum of the secondary residual curves is greater than the uncorrected primary curve no correction is possible. If the uncorrected primary is only 20 to 30 degrees greater than the sum of the uncorrectible secondary curves, little correction is possible. He advocates a pre fusion composite film

composed of sections of three roentgenograms. The lumbar curve is the lumbar segment from the "pelvic tilt" film, the upper dorsal curve is taken from the "side bending" film, and the primary curve is obtained from the final correction film through the Risser jacket. These three segments are fixed together, and postoperative compensation is studied as follows: If D 1 is over the sacrum, the curve is corrected. If the first dorsal vertebra is displaced to the side of the concavity of the primary curve it is undercorrected. If the first dorsal vertebra is displaced to the side of the convexity of the primary curve it has been overcorrected.

Butte has admirably summed up the answers to this problem as follows:

1 The minimum fusion area must include every vertebra in the primary curve. There is an occasional exception to this rule in cases where one vertebra at one or the other end of the primary curve may be omitted from the fusion. The primary curvature is that curve in which the deforming factor is active and for which the other curve or combination of curves is compensatory. Occasionally there are two primary curvatures.

"2. The ideal fusion area is one which includes at least the minimum fusion area and in which the end vertebrae are parallel to each other and at right angles to the line joining their centers. In the final result the end vertebrae of such a fusion will be parallel and transverse to the axis of the trunk.

"3 The actual determination of the fusion area whether or not one or more vertebrae beyond the ends of the primary curvature should be included, is made after correction has been obtained by the wedging jacket.

4 Overcorrection of a curvature and fusion in this position is to be avoided.

"5 Provided thereby compensation has been restored, remarkable improvement in clinical and roentgenographic appearance often results when the primary curve has been corrected less than 50 per cent."

Application of Risser Turnbuckle Jacket Cast.—With the patient in a supine position on a Hibbs frame or a modification thereof (Fig 1071), a plaster cast is applied from the chin and occiput to the pelvis for high dorsal curves; for lower curves the cast should extend to the knee on one side. During the application of the cast, traction is maintained on the head only sufficiently to hold it steady on the head rest. The head is tilted toward the side of the concavity of the curve thus preventing undue stretching of the brachial plexus as correction of the scoliosis begins. Metal hinges are incorporated in the front and back of the cast eccentric toward the convexity of the curve; frequently the center of these hinges is below the actual center or apex of the curve. A turnbuckle is incorporated on the lateral aspect of the cast on the concave side of the curve.

After the cast has dried sufficiently a circular cut is made around the cast at the level of the hinges. On the side opposite the turnbuckle a large elliptical window is removed, a space being allowed in which bending may take place with subsequent turns of the turnbuckle. The edges of the cast must be beveled and careful attention must be directed toward the prevention of pressure sores.

Correction of the scoliosis may require two to three weeks or may require the application of a new cast to obtain complete correction as determined by roentgenograms. Vom Saal states that the posterior rib deformity may be reduced and the operation simplified by removal of the hinges and turnbuckle

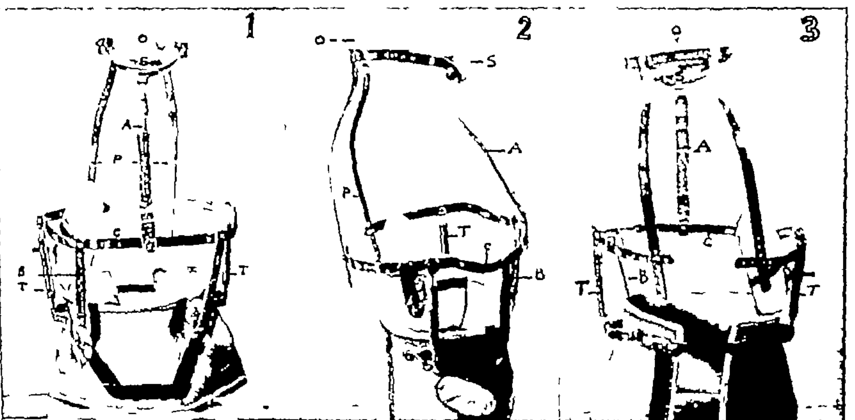


Fig. 1074.—Milwaukee brace. *1* Front view: *A*, Adjustable aluminum anterior support. *B* Adjustable anterior bars. *C* Single transverse bar. *O* Notched occiput support. *P* Removable posterior support. *S* Platform chin support. *T* Turnbuckles. *2* Side view. *3* Back view. (Courtesy of Dr. W. P. Blount.)



Fig. 1076.—Milwaukee brace adjusted to patient with scoliosis, dorsolumbar right. (Courtesy of Dr. W. P. Blount.)

after correction has been obtained and shifting of the shoulder forward on the convex side The cast is then completed. In this manner the plane of the spinous processes is changed from the horizontal to vertical by the process of derotation. After correction is complete all defects in the cast are filled with plaster and a large posterior window is created to provide adequate exposure for arthrodesis.

Milwaukee Scoliosis Brace (Blount and Schmidt) —The ordinary method of treating scoliosis by a preliminary corrective Risser jacket followed with fusion is reversed in the Blount-Schmidt technic. First, a Milwaukee brace (Fig 1074) is made from a model applied over the patient's torso during suspension. This step in the procedure requires an experienced bracemaker and the surgeon must be willing to devote considerable time to checking the fit If necessary the brace should be *remodeled as the correction proceeds.* At all times during and following the correction the patient should be able to raise his chin and occiput simultaneously from the head support, or rest his head on the support and move his body away from the lateral pressure pad, in order to avoid pain or undue pressure

The brace is worn for a period of from two weeks to two months, until the patient becomes accustomed to its pressure and is then removed for the operation. After the first stage of fusion has been completed, dressings are applied and the brace is readjusted Every day or two the turn buckles and lateral pressure pads are advanced sufficiently to take up slack

If necessary a second stage of the fusion is carried out approximately two weeks later After the second stage the curve may be further corrected over a period of approximately two weeks correction should then be complete. Bed rest is continued for four months after the last operation Usually the brace should be worn for six to eight months following fusion

Technic of Fusion

Prior to operation a known anatomic landmark must be established To accomplish this the skin over a spinous process in the area to be fused is marked with gentian violet A piece of metal is strapped on this mark, and roentgenograms are made definitely establishing the location of the spinous process of a particular vertebra If this precaution is not observed, the fusion may be carried out lower or higher than anticipated thus adversely affecting the end result.

In some cases, a primary curve may be so extensive as to prevent the accomplishment of fusion at one operation Ordinarily six to eight vertebrae may be fused at the first operation. If two fusions are contemplated the first arthrodesis should be centered over the apex of the primary curve and the second at the extremities of the primary curve By this method the grafts are not overlapped at the point of most stress, and the possibility of failure of the fusion is minimized.

Both of the classical methods of spinal fusion present technical difficulties in a scoliotic spine. The straight, rigid Albee graft is not adaptable to the curve of the deformity By the Hibbs technic, the laminae and articular facets on the concave side are difficult to expose.

Multiple thin grafts from the ilium or tibia are most suitable. These grafts, which may be applied in combination with a simplified Hibbs or Albee

operation provide a large mass of new bone which is flexible and easily accommodated to the area of deformity (see chapter on Arthrodesis) Should the ribs be prominent a portion of a rib may be resected and used as an additional graft at the time of the modified Hibbs operation Henry's method of fusion is particularly applicable to scoliosis Some of the undesirable features of fusion may be altered if grafting with bone preserved by freezing should prove to be efficient and practical

The patient should be adjusted in the prone position on sandbags, by this means respiration which is already limited by the deformity, is not further impaired Intratracheal anesthesia is preferable Since fusion is carried out through a window in the cast instruments should be available for immediate removal of the cast in the event of undue respiratory embarrassment

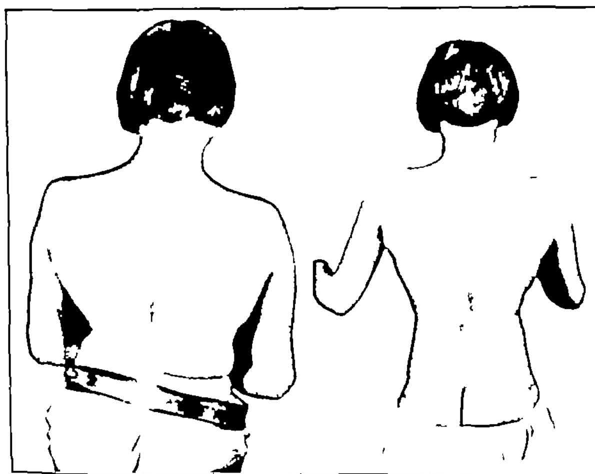


Fig 1076.—Before and eighteen months after correction of scoliosis and fusion of corrected curve.

After Treatment.—Recumbency in the original cast is maintained for a period of three months following the last operative procedure Subsequently a semi bent jacket cast is applied with the patient in a supine position no attempt being made to straighten the spine more than is possible without effort The patient may then be ambulatory Casts are reapplied at intervals, roentgenograms being made to check the status of fusion and maintenance of correction. Ordinarily rather rigid fixation will be necessary for six to nine months after operation.

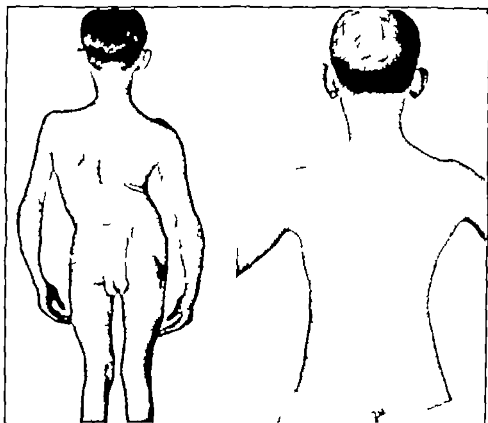


Fig. 1077.—Paralytic scoliosis corrected by turnbuckle cast with subsequent fusion of spine.

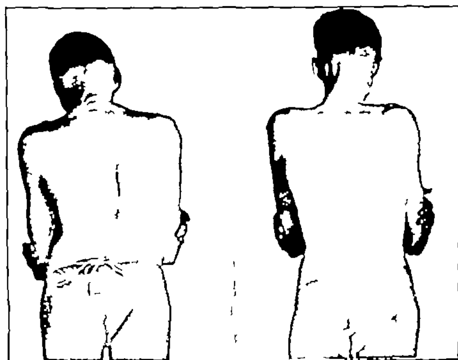


Fig. 1078.—Paralytic scoliosis before and after correction and fusion of spine.

Complications—Pressure sores occasionally develop in the region of unprotected bony prominences such as the chin, occiput iliac spines, ribs and scapula For this reason these areas must be carefully padded with felt before the cast is applied

Brachial plexus palsy is a serious complication regardless of when it appears Its presence indicates either traction on the cervical nerve roots or direct pressure by an inadequately padded chin and neck piece Correction should be interrupted until the symptoms subside and further correction must be carried out with extreme care

One of the most common complications of arthrodesis is pseudarthrosis of the fusion mass usually at the apex of the curve This is manifested by localized loss of correction fatigue pain radiating along the intercostal area and local tenderness near the crest of the curve When this situation arises, correction should again be undertaken followed by exploration of the entire graft area and reinforcement by additional bone grafts as necessary

Delayed union of the fusion mass is a serious complication and is manifested by a gradual and generalized loss of correction in the fused area during the immediate postoperative period In addition to the superincumbent body weight the fusion mass must withstand the tendency of the contractures to pull the spine into the original deformed position For this reason adequate support must be continued for at least seven to nine months following the fusion operation

References

Abbott, L. G : Correction of Lateral Curvature of the Spine New York M. J 95: 833 1912.

Bartlett R. W A Conservative Operation for the Cure of So-Called Ingrown Toenail, J A M. A. 108 12.7 1037

Bett L. O : Morton s Metatarsalgia Neuritis of the Fourth Digital Nerve, M J Au tralia 1 514 1040

Blount W P., and Schmidt A C : Unpublished data.

Butte Felix L.: Navicular-Cuneiform Arthrodesis for Flat Foot, J Bone & Joint Surg 19 496, 1937

—: Scoliosis Treated by the Wedging Jacket. Selection of the Area to Be Fused, J Bone & Joint Surg 20 1 1038.

Campbell, Willis C Infraction of the Head of the Second and Third Metatarsal Bones: Report of Cases Am. J Orthop Surg 15 721 1917

Chambers, L. F R.: An Operation for Correction of Flexible Flat Feet of Adolescents, West. J Surg 54: 1040.

Clark, W A : A Rebalancing Operation for Pronated Feet J Bone & Joint Surg 13 807, 1931

Cleveland M., Willien L. J., and Doran P C. Surgical Treatment of Hallux Valgus in Troops in Training at Fort Jackson During the Year of 1942, J Bone & Joint Surg 26 531 1944

Cobb J R.: Observations on the Treatment of Idiopathic Scoliosis (Unpublished) 1948

Ferguson, A. B : *The Study and Treatment of Scoliosis, South. M J* 23 116 1930.

Fowler G R.: A Treatise on Surgery Vol. II Philadelphia 1907 W B Saunders Co., p. 622.

Freiberg, A. H. A Method of Passing Bone Sutures at a Depth, with Observations on Extensor Contracture of the Fifth Metatarsal Bone, J Bone & Joint Surg 7 400 1925

— The So-Called Infraction of the Second Metatarsal Bone J Bone & Joint Surg 8 257 1926.

Galeazzi, R.: The Treatment of Scoliosis, J Bone & Joint Surg 11 81 1929

Girdlestone, G R., and Spooner H. G A New Operation for Hallux Valgus and Hallux Rigidus, J Bone & Joint Surg 19 30 1937

Harris, R. I., and Beath T : Hypermobile Flat Foot With Short Tendo Achillis, J Bone & Joint Surg 30-A 116 1948.

Heifetz, C J : Ingrown Toe-Nail Am. J Surg 38 298 1937

Heuter Quoted by Holmes, T System of Surgery Vol. 3 Philadelphia 1882, Henry C. Lea s Son & Co., p 372

Hibbs, Russell A.: A Report of Fifty Nine Cases of Scoliosis Treated by the F Operation, J Bone & Joint Surg 6 3, 19 4.
Hibbs, Russell A., Risser J C., and Ferguson, A. B: Scoliosis Treated by the F Operation, J Bone & Joint Surg 13 91 1931.
Hoke, Michael: *An Operation for the Correction of Extremely Relaxed Flat Feet, J* & Joint Surg 13 773, 1931
Jansen, Murk March Foot J Bone & Joint Surg 8 262, 1926.
Jones, Sir Robert The Soldier's Foot and the Treatment of Common Deformiti the Foot. Part III Hammer Toe, Brit. M J 1: 782, 1916.
Keller W L.: Further Observations on the Surgical Treatment of Hallux Valgu Bunions, New York M. J 95: 696, 1912.
Kidner F C. The Prehallux (Accessory Scaphoid) in Its Relation to Flat Foot, J & Joint Surg 11 831 1929
— The Prehallux in Relation to Flatfoot, J A. M. A 101: 1539 1933
Kleinberg S. Scoliosis, New York, 1926 Paul B. Hoeber Inc.
— The Operative Cure of Hallux Valgus and Bunions, Am. J Surg. 15 75 1932.
Lapidus, P W: Operative Correction of the Metatarsus Varus Primus in Hallux V *Surg. Gynec. Obst. 58: 183 1934.*
Lapidus, P W: Transplantation of the Extensor Tendon for Correction of the lapping Fifth Toe J Bone & Joint Surg 24 555 194_
Lapidus, P W Spastic Flat Foot J Bone & Joint Surg 28 126 1946.
Lewin Philip: Calcaneal Spurs, Arch Surg 12 117, 1926.
Lovett, R. W., and Brewster A. H. The Treatment of Scoliosis by a Different M from That Usually Employed J Bone & Joint Surg. 6 847 1924.
Lowman, C. L.: An Operative Method for Correction of Certain Forms of Fla J A M. A. 81: 1500, 1923.
Markellov N., and Ilin A.: The Surgical Therapy of Calcaneal Spurs, Ortop. i travi 7 49 1933
Mayo, C. H. Collected Papers by the Staff of St. Mary's Hospital, Mayo Clinic, 1909 p. 559
— The Surgical Treatment of Bunion Ann. Surg. 48 300 1908.
McElvenny R. T: The Etiology and Surgical Treatment of Intractable Pain Abou Fourth Metatarsophalangeal Joint (Morton's) J Bone & Joint Surg 25 1943.
McBride Earl D A Conservative Operation for Bunions, J Bone & Joint Surg. 10 1928.
—: The Conservative Operation for Bunions. End Results and Refinement Technic, J A M. A. 105 1164 1935.
Miller O L.: A Plastic Flatfoot Operation, J Bone & Joint Surg 9: 84, 1927
Mills, G P The Etiology and Treatment of Claw Foot J Bone & Joint Surg 6 14_
Mitchell, J I. The Etiology and Treatment of Scoliosis, Arch. Surg 16 680 1928.
Nissen, K I: Plantar Digital Neuritis—Morton's Metatarsalgia, J Bone & Joint 30-B 84 1948.
Peabody C. W: The Surgical Cure of Hallux Valgus, J Bone & Joint Surg 13 1931
Peabody C. W., and Muro, Felipe: Congenital Metatarsus Varus, J Bone & Joint 15 171 1933
Porter J L.: Why Operations for Bunion Fail with a Description of One That Does Surg Gynec. Obst. 6: 89 1900
— Some Further Notes on the Treatment of Bunions, Surg Gynec. Obst. 26: 1918.
Preston, Robert L.: Scoliosis, Internat. Abstr Surg 59 1 1934.
Riedel Zur operativen Behandlung des Hallux Valgus, Zentralbl. f Chir 13 753,
Risser J C: Acquired Scoliosis, The Cyclopedia of Medicine Philadelphia, 11: 435 F A. Davis Co.
Risser J C.: Observations on the Treatment of Idiopathic Scoliosis (Unpublished)
Risser J C., and Ferguson A. B.: Scoliosis Its Prognosis, J Bone & Joint Surg 667 1936.
Rogers, W A and Joplin R J: Hallux Valgus, Weak Foot and the Keller Opera An End Result Study, S. Clin North America 27: 1293, 1947
Shands, A. R. Jr Barr J S, Colonna, P C. and Noall L.: End Result Study of Treatment of Idiopathic Scoliosis; Report of the Research Committee of American Orthopaedic Association J Bone & Joint Surg 23 963, 1941
Silver David The Operative Treatment of Hallux Valgus, J Bone & Joint Surg 225 1923
Smith A. DeF., Butte, F L., and Ferguson A. B.: Treatment of Scoliosis by the W ing Jacket and Spine Fusion; A Review of 265 Cases J Bone & Joint Surg 825, 1938
Soule R. E. Value of Bone Pin Arthrodesis in the Treatment of Flat Foot, J A. M 77: 1871, 1921

Speed, J S and Blake T H: March Foot J Bone & Joint Surg 15 3/3, 1933
Steindler A., and Smith, A R: Spurs of the Os Calci Surg Gynec Obst. 66 663 1938
Stuart F W: Claw Foot—It Treatment J Bone & Joint Surg 6 360 10?4
Truslow Walter: Metatarsus Primus Varus or Hallux Valgus? J Bone & Joint Surg 7 98, 19?5.
Vom Saal Frederick: Management of Scoliosi Am. J Surg 52 433 1941
Von Lackum W H: Surgical Treatment of the Motor Skeletal System Bancroft and Murray Philadelphia, 1945 J B. Lippincott Co.
Whitman, Royal: Observation on the Operative Treatment of Scolio is, J Orthop Surg 3 330, 19-1
Winograd, A. M A Modification in the Technic of Operation for Ingrown Toe-Nail J A M A 92 229 19?9
Young C. S.: An Operation for the Correction of Hammer Toe and Claw Toe, J Bone & Joint Surg 20 15, 1938.
Young J K: The Etiology of Hallux Valgus or the Intermetatarseum Am. J Orthop Surg 7: 336 1909 10
—: A New Operation for Adolescent Hallux Valgu Univ Pennsylvania Med. Bull. 23 4?9 1910-11
Zadek, Isadore: Transverse Wedge Arthrodesi for the Relief of Pain in Rigid Flat Foot, J Bone & Joint Surg 17 4?3 193?

CHAPTER XXV

CONGENITAL ANOMALIES

Congenital anomalies may be classified as (1) atrophy or hypertrophy of a region or member, (2) numerical variations, and (3) developmental abnormalities. Only congenital anomalies which are amenable to treatment will be discussed, i e., asymmetrical (atrophic or hypertrophic) development of one or more regions or members, constrictures of the legs, abnormalities of the fingers and toes, deformities of the foot, congenital absence, defects, or pseudoarthroses of the long bones, congenital recurvatum dislocation of the knee and hip coxa vara, anomalies of the vertebrae cervical ribs, torticollis, congenital elevation of the scapula, congenital radio-ulnar synostosis, Madelung's deformity and arthrogryposis multiplex congenita.

ASYMMETRICAL DEVELOPMENT

Asymmetrical development may be the result of atrophic or hypertrophic growth of one half of the body (hemihypertrophy or hemiatrophy) or of an extremity or part of an extremity

ATROPHIC ANOMALIES

This type of anomaly is seldom corrected by surgery the operative procedures employed are not curative, but merely palliative or compensatory For example, in congenital hemiatrophy blocking of the epiphyses of the normal lower extremity (p 1440) at the proper age may retard growth of that member ultimately compensating for the shortening of the affected extremity Or after full growth is attained the normal limb may be shortened by resection of a portion of a bone by the Z-plastic method (p 1454) Various operations have been devised for lengthening shortened lower extremities (p 1427) these however are extensive. Atrophic anomalies of the fingers, toes, hands, or feet are seldom amenable to surgical treatment. Amputation may be indicated if the deformity is unsightly or interferes with function.

HYPERTROPHIC ANOMALIES

Hypertrophic anomalies of congenital origin are observed less frequently than hypertrophy of an extremity or region induced by definite etiologic agents, such as tumors (lymphangioma, neurofibroma), circulatory disturbances (arteriovenous aneurysm) or infection (osteomyelitis)

When an entire extremity is involved the joints may be extremely distorted as a rule, however all the muscles are active but atrophic from disuse. The etiologic agent is removed, when possible, to prevent further discrepancies in length and size. Equality of length is then accomplished by arrest of epiphyseal growth or by plastic procedures for shortening the affected extremity

In the majority of cases, hypertrophy must be reduced by operative measures on the bones and soft structures these must be planned to meet

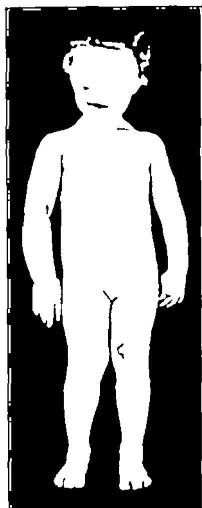


Fig. 1039.—Congenital asymmetrical development. Note difference in level of finger tips and of patella and in circumference of arms.

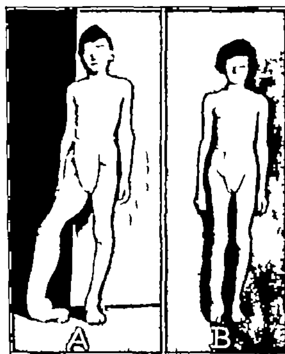


Fig. 1040.—A Hypertrophic anomaly of right lower extremity secondary to diffuse neurofibromatosis. B After removal of tumors, reconstruction (see text) and Z-plastic step-cut shortening of femur

the requirements of the individual case. The possibilities of reconstruction surgery are exemplified by the following case of hypertrophy of an extremity associated with a diffuse neurofibromatosis

CASE REPORT—The patient was a white girl, aged fourteen years. When she was one and one-half years old her mother noticed that her right ankle and foot were enlarged. As the child grew, the increase in size gradually continued, ultimately involving the entire right lower extremity

On physical examination the limb was massively hypertrophied and was five and one-half inches longer than the normal one. Elongated masses were apparent throughout its length. The only deformity was an equinovarus of the foot.

Incisions twelve to eighteen inches long on the thigh and leg exposed many cylindrical tumors, some of them twelve inches in length. On microscopic study the growths were found to be neurofibromata. After removal of all the tumors and healing of the wounds, the circumferences of the leg and thigh were practically normal. The length of the tibia was then decreased approximately two and one-half inches and the foot stabilized by the technic described below for shortening of the lower third of the leg and correction of equinovarus deformity

Technic.—The subastragalar astragaloscaphoid and calcaneocuboid joints are exposed through a long anterolateral incision (p 137) and the astragalus is completely resected The lower two inches of the bones of the leg are next exposed and one and one half inches are removed from the end of each. As the lower tibial and fibular epiphyses are thus destroyed growth of the extremity is retarded With an osteotome, a new ankle joint including an internal and external malleolus, is remodeled from the lower end of the tibia and fibula. A cavity one inch in depth is created in the ends of these bones, the foot is displaced backward and the superior surface of the os calcis inserted into the cavity Finally an arthrodesis is performed on the mid tarsal joints (p 1320)

After Treatment.—A plaster cast is applied from the toes to the mid thigh, holding the knee in 90 degrees flexion and the foot in moderate equinus. At the end of eight weeks this cast is replaced by a walking cast extending from the toes to just below the knee, and maintaining the foot in the same position. After four weeks, the cast is removed and weight bearing permitted with the aid of a limited motion ankle brace. The brace may be discarded six months postoperatively

Since a discrepancy of three inches in the length of the patient s lower extremities remained after the above treatment, the femur was shortened by a Z-plastic step-cut operation (p 1454)

Following these operations, the muscles and soft tissues were so relaxed that they literally hung in festoons and there was considerable anxiety as to their future function. Much to our surprise, however when the cast was removed the soft tissues were found to have contracted to a degree commensurate with the shortening The patient s limbs were of approximately the same length, and when walking was resumed her gait was practically normal, although there was less strength in the affected member

CONSTRICTURES OF THE LEG

Congenital circular constrictures of the soft tissues of the leg are rare anomalies. All the tissues from the skin through the deep fascia are involved, although as a rule, the lymphatics and superficial circulation are only partially impaired The lesion is demonstrable at birth as a circular depression of the soft tissues with dimpling of the skin over the constricted band. Frequently a clubfoot deformity is associated.

Technic.—Two circular incisions are made around the leg one on each side of the constricture into normal soft tissues and the intervening skin subcutaneous and deep fascia are removed The edges of the wound are undercut sufficiently to permit closure of the skin and subcutaneous struc tures without tension If closure is difficult sliding double pedicle grafts



Fig 1081.—Specimens of tumors (neurofibromata) removed from lower extremity of patient shown in Fig. 1080

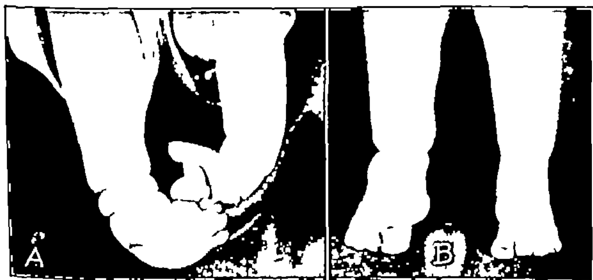


Fig. 1082.—A Congenital constrictures of leg associated with bilateral club foot. B After cor rection of equinovarus deformity and plastic operation (see text)

may be utilized to repair the defect. The raw area created by removal of the sliding graft is covered with Thiersch grafts.

Results of this procedure are not always satisfactorily, as some degree of edema of the leg and foot may persist.

ABNORMALITIES OF THE FINGERS AND TOES

The most common variation of the fingers and toes is polydactylism, or supernumerary digits. Other anomalies which may require surgical correction are *syndactylism (webbed fingers) macrodactylism (enlarged fingers)*, and congenital contracture or angulation.

POLYDACTYLISM

When the digits are increased in number the operative technic must meet the requirements of the case in question. The selection of the toe or finger for removal should be made with the idea of providing a normal contour

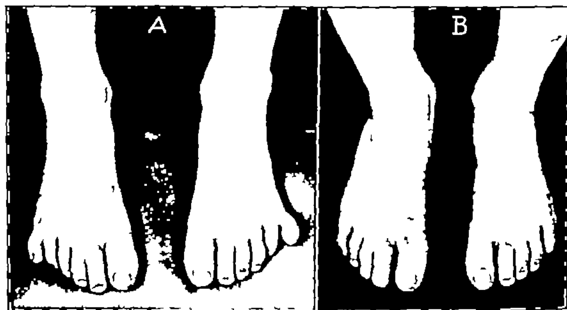


Fig. 1083 —Supernumerary toes, before and after operation.

of the foot or hand as well as retaining the toe or finger wherein musculature and function are more nearly normal. Thus, if the length and contour of the sixth finger are that of the normal little finger the fifth should be amputated. This is more often necessary in the hand than in the foot usually, amputation of the sixth toe is sufficient. In the presence of corresponding supernumerary metatarsal or metacarpal bones as revealed by roentgenograms, amputation must be performed at the tarsometatarsal or carpometacarpal joint. The accessory finger or toe, however is generally an outgrowth from the distal end of the normal metacarpal or metatarsal bone.

Technic.—An oval or circular incision is made at the base of the digit to be amputated and carried through the fasciae. The tendons are drawn out as far as possible and severed The capsule of the proximal joint is dissected from the bone by a transverse dorsal incision, the joint is disarticulated, the entire capsule resected and the digit amputated. With an osteotome or bone forceps, any protrusion of bone supporting the articular surface is removed.

If an extra metacarpal or metatarsal bone is revealed in the roentgenogram, this may be excised on continuing the oval incision down the lateral or dorsal aspect of the hand or foot.

SYNDACTYLISM

The methods of correction of congenital webb fingers or syndactylism comes within the province of plastic surgery Readers are referred to stand ard works on this subject

MACRODACTYLISM

Macrodactylism is an hypertrophy overgrowth or overdevelopment of one or more fingers or toes. Function of the digit may or may not be normal Treatment is sought as a rule for cosmetic reasons rather than for the disability incident to the deformity Occasionally, plastic operations may be employed to render the deformity less obnoxious to the patient and less notice able to others usually, however, the patient prefers to have the digit amputated.

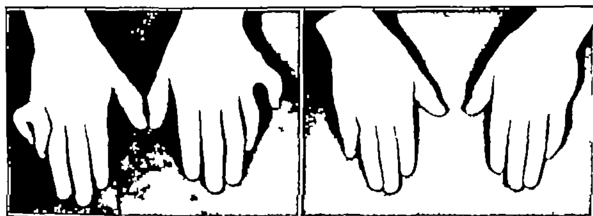


Fig 1614.—Polydactylism before and after plastic amputation of supernumerary fingers.

CONGENITAL CONTRACTURE OR ANGULATION OF THE TOES OR FINGERS

Congenital contracture or angulation of the fifth toe or finger is not an un common familial deformity In the foot overlapping of the fifth toe upon the fourth causes practically no disability Congenital hammertoe or claw toe may be treated according to the techniques described in Chapters XXII and XXIV

Congenital Subluxation of the Fifth Toe

Congenital subluxation of the fifth toe presents a varus deformity with a dorsal subluxation of the metatarsophalangeal joint in addition the entire toe is adducted and rotated externally thus overlapping the fourth toe

Technic (Lapidus) —Along the dorsomedial border of the fifth toe a longitudinal hockey-stick incision is made extending from the distal inter phalangeal joint to the webb between the fourth and fifth toe from the prox imal end of the incision the hook of the hockey stick is added by extending the incision over the dorsum of the fifth metatarsal joint laterally and proximally to the lateral aspect of the fifth metatarsal head The fifth toe is extended in order to taut the extensor longus tendon

A one centimeter transverse incision is now made at a point corresponding to the middle of the fifth metatarsal bone The extensor longus tendon to the fifth toe is cut transversely through this incision and its free distal end is retracted out of the wound over the fifth toe. The distal end of the tendon is then completely freed to its insertion into the distal phalanx. The capsule of the fifth metatarsophalangeal joint is exposed by blunt dissection and severed transversely on its dorsal and medial aspect. A channel is now made starting near the distal interphalangeal joint on the dorsomedial aspect of the toe winding around the plantar surface in a proximal and lateral direction, ending on the plantar lateral aspect of the fifth metatarsophalangeal joint The extensor tendon of the fifth toe is now passed through this tunnel encircling the medial and plantar surface of the fifth toe in a spiral oblique fashion. The free end of the translocated tendon is sutured under tension into the abductor and short flexor of the fifth toe which have been split longitudinally to facilitate the anchorage The skin is closed with interrupted sutures. If there is extensive skin contracture it is necessary to shift the opposite edges of the skin against each other or do some additional plastic surgery

After Treatment.—The toe is immobilized by a well moulded short steel corset splint loosely applied. The splint is worn for three to four weeks. Ambulation is allowed in a cut-out shoe

Lantzounis reports nineteen cases of this condition wherein he operated with gratifying results

Technic (Lantzounis)—*Under a tourniquet a two-inch longitudinal skin* incision is made over the dorsal surface of the fifth metatarsophalangeal joint. At the distal end of the incision, the extensor digitorum longus tendon is isolated and severed A longitudinal cut is then made through the capsule and through the periosteum of the distal end of the fifth metatarsal and the proximal phalanx and these structures are elevated subperiosteally from the dorsal lateral and medial surfaces. A tunnel is next drilled through the distal end of the fifth metatarsal and the proximal end of the severed tendon is threaded through and sutured back on itself The periosteocapsular flap is now attached in place by a mattress suture The suture is started laterally and proximally to the metatarsal head the needle is passed beneath the metatarsal neck to the medial flap proximally next to the medial flap distally and then under the neck of the phalanx and through the lateral flap distally Before the mattress suture is tied the toe is plantar flexed The wound is then closed in layers. The toe is maintained in the corrected position by adhesive strapping for a period of three weeks.

Goodwin suggests the following operation for this condition

Technic (Goodwin)—Under a tourniquet, a Y-shaped incision is made on the dorsum of the foot at the base of the involved toe, the stem of the incision extending proximally over the extensor tendon the crotch lying over the extensor tendon and over the metatarsophalangeal joint, and the branches of the Y extending distally about halfway around the toe. The extensor tendon is exposed and lengthened by the Z-plastic method and the joint capsule is cut at least 180 degrees around the joint. The toe should now fall into the corrected position. The tendon is then sutured loosely The skin is closed, beginning at the proximal end of the stem the triangular flap of skin being allowed to slip distally A plaster cast is applied for ten days thereafter adhesive strapping is used for six weeks.

Congenital Contracture of the Fifth Finger

In the fingers contracture gives the appearance of an affectation, and many individuals, particularly men seek correction for this reason alone Generally, the deformity consists of a flexion contracture of the first inter phalangeal joint with a valgus deformity, the little finger tending to overlap the fourth The following technic is appropriate only for severe deformity, usually, a skin plastic procedure suffices.

Technic.—In order that the scar may not be conspicuous, an incision one inch in length is made along the radial side of the finger, the nerves and vessels being avoided The periosteum is stripped from the distal end of the first phalanx proximal to the head An anterior capsulotomy should not be per formed, as the joint will be dislocated when correction of the flexion contrac ture is attempted With a small osteotome a wedge shaped section of bone is removed just proximal to the interphalangeal joint, the base of the wedge being toward the ulnar side of the hand Sufficient bone is resected to permit correction of both the valgus and flexion deformities

After Treatment.—The finger is placed in a Lewin finger splint or in a snugly fitting molded plaster splint which covers three-fourths of the circum ference of the finger and extends proximally on the anterior surface of the wrist. As the plaster consolidates, the finger is correctly aligned Roentgeno-grams are made after ten days to check the apposition and alignment of the fragments. Physical therapy usually is begun at four weeks.

CONGENITAL HALLUX VARUS

Hallux varus is a deformity wherein the toe angulates medially at the metatarsophalangeal joint. This deformity should not be confused with meta tarsus primus varus deformities In the latter the entire first ray is angu lated medially at the tarsometatarsal joint.

From a survey of the literature McElvenny reports that one or more of the following conditions are usually present (1) the first metatarsal bone is usually thicker and shorter than normal (2) accessory bones or toes are often associated with the deformity (3) varus deformities of one or more of the other metatarsal bones may be associated and (4) a firm fibrous tissue band extends from the inner side of the great toe to the base of the first metatarsal bone.

This deformity is explained as a congenital abnormality wherein a pri mary double hallux originates in embryo the medial toe or accessory one fail ing to develop beyond a certain stage Subsequently, the imperfect toe to-gether with the fibrous tissue band serves as a taut bow string which gradu ally draws the great toe into a varus position.

Treatment consists of amputation or a plastic procedure to restore the general appearance and alignment of the great toe

Technic (McElvenny) —A defect is created in the web between the first and second toes to produce an artificial syndactylism Two longitudinal in cisions are then made one over the anteromedial aspect of the metatarso-phalangeal joint, and another of similar length paralleling the medial border of the operative field The capsular flap is turned distally allowing exostec tomy of the bony prominence of the distal and lateral aspect of the meta tarsal head. Through the anteromedial incision the accessory bone and the sesamoid bone of the flexor tendon are excised with the medial fibrous tissue

a completely abducted and pronated foot." Later the posterior deformities are corrected by triple arthrodesis after the manner of Hoke, Ryerson, or others.

CONGENITAL CAVUS

Operative treatment for this anomaly is not advisable until the patient reaches the age of six or eight years. The technic is identical to that described for cavus from poliomyelitis (p 1331) As cavus is often associated with spina bifida, sensation may be diminished and care must be taken to avoid trophic changes from pressure.

CONGENITAL EQUINOVARUS

A knowledge of the pathologic changes in the bones and soft tissues in congenital clubfoot is necessary to the selection of appropriate treatment. This deformity varies in severity from mild equinus and varus of the foot, to extreme deformity consisting of equinus, varus or inversion, cavus, adduction of the forefoot and internal rotation of the tibia. Internal rotation of the tibia of 15 degrees or more should be corrected surgically Changes in the soft structures consist principally of contracture of the plantar ligaments on the medial side of the foot, of the deltoid ligament, the posterior tibial tendon and frequently the anterior tibial tendon and the tendo achillis. In the newborn infant, changes in the soft tissues are more pronounced than those in the bones. After a short time, however, the contours of the tarsal bones become distorted to conform to the contractures of the soft tissues. There is some disagreement upon this point. Brockman for example, believes that the primary deformity is principally the result of congenital atresia of the articulation for the head of the astragalus, and that the remaining pathologic changes center about this abnormality The chief deformity of the tarsal bones is evidenced in the astragalus and os calcis. The latter is inverted and angulated, so that the anterior extremity is displaced toward the medial side of the foot. The astragalus may be deviated medially and downward to such a degree that a portion of its articular surface lies outside the ankle mortise. At the astragaloscaphoid joint the articular relations are altered the scaphoid bone being displaced medially and rotated so as to articulate only with the inferior and medial aspects of the head of the astragalus. In turn, the head of the astragalus forms a subcutaneous osseous prominence on the dorsum of the foot.

The treatment of congenital clubfoot should begin within two weeks after birth, as the difficulty of securing proper correction of the deformity increases with age Either operative or nonoperative measures may be employed

Nonoperative Treatment

In our hands, the wedge cast method of Kite has been the most successful nonoperative procedure. Kite states that 90 per cent of all clubfeet can be corrected by wedge casts. Blumenfeld Kaplan and Hicks report good results in approximately 80 per cent treated conservatively

The order in which the component parts of the deformity are corrected is as follows first, the varus of the foot and adduction of forefoot, second, the cavus deformity and inversion of the os calcis and last, the equinus.

After proper correction of the inversion and adduction of the foot, surgical intervention (p 1018) may be necessary to correct a persistent equinus deformity

Operative Treatment

Operative treatment should be reserved for older children with neglected clubfeet even in this group the deformity must be corrected by conservative measures, in so far as possible before operation is undertaken Operations should be performed only on the soft tissues in children up to six or eight years of age before this period ossification is not sufficiently well advanced for fusion and a recurrence of the deformity is inevitable Beyond this age operations on the bone are permissible

Correction of Congenital Equinovarus by Soft-Tissue Operations (Three to Eight Years)

In cases which have not responded fully to conservative treatment, surgery may be necessary in order to complete the correction Brockman has devised a procedure which is based entirely upon the hypothesis that the deformity is primarily due to a congenital atresia of the socket for the head of the astragalus, and aims at making this socket sufficiently large to enable it to be replaced in its normal position, and in addition it is necessary to lengthen the muscles which control the variations in capacity of this socket The operation is carried out in two stages, which is a slight disadvantage.

Technic (Brockman) —An incision is first made on the outer side of the foot over the os calcis and the plantar muscles, and the fascia is detached as far backward and inward as possible A second incision is made on the inner side of the foot and the remaining attachments of these muscles are completely severed. The sheath of the tibialis posticus tendon is elevated and opened as it passes to the scaphoid bone, and the tendon is divided if contracted All structures are dissected free over the inferior surface of the tarsal bones, to expose the inferior and medial surfaces of the scaphoid and the inner aspect of the sustentaculum By movement of the foot the articulation between the scaphoid and os calcis is identified and all the ligaments on the inner aspect of this joint are divided The foot is then abducted and dorsiflexed, bringing the scaphoid in front of the head of the astragalus and moving the anterior portion of the os calcis laterally from beneath the astragalus. The foot should remain corrected without the use of force otherwise contracted soft tissue structures persist, preventing adequate correction.

After Treatment.—A plaster cast is applied though the foot is not maintained in full correction this would lead to interference with circulation and consequent sloughing of the soft tissue structures about the incision. Two weeks postoperatively the cast is removed and the deformity is fully corrected while the stitches remain in situ The equinus deformity is also corrected at this time by lengthening of the tendo achillis. A snugly fitting plaster cast is applied and walking allowed for a period of six to eight weeks. Physical therapy is then instituted effort being especially directed toward teaching the child to evert the foot voluntarily

Brockman states that, with gentle dissection there is little reaction and thus no tendency to the formation of large quantities of fibrous tissue which might contract and lead to recurrence of the deformity

Correction of Tibial Torsion Accompanying Congenital Equinovarus

If, after correction of the feet, a decided improvement is not apparent following a reasonable period of growth, internal torsion should be corrected

surgically According to Sell, who observed this deformity in 17 per cent of 62 consecutive clubfeet, surgery is advisable if the rotation is 15 degrees or more.

The O'Donoghue method of controlled osteotomy (p 1369) is recommended. The technic for external rotation of the distal portion of the tibia on the proximal segment requires that the distal transverse cut be on the outer side of the tibia i e. in the direction of the desired correction

Anterior Tibial Tendon Transposition in Recurrent Clubfoot

Garceau and Peabody are of the opinion that talipes equinovarus results from a prenatal muscle imbalance due to an imperfect development of pronator and extensor function that often a permanent residual insufficiency prevails in the three peroneals and that when this insufficiency is demonstrated in recurrent cases, transposition of the anterior tibial tendon is indicated Garceau has employed this operation in 6 7 per cent of 1,275 patients.

Technic (Garceau)—A one-inch longitudinal incision is made just above the ankle joint over the anterior tibial tendon. The insertion of the tendon is exposed detached and pulled through the upper incision. A curved hemostat is passed through the upper incision and distally under the annular ligament, toward the proximal end of the fifth metatarsal. A short incision is next made over the fifth metatarsal and a hole is drilled in the bone. A silk suture is placed in the tendon and the tendon is passed through the channel and drill hole and securely anchored If short, the tendon is transferred to the cuboid

After Treatment.—A circular plaster cast is applied maintaining as much correction as possible. After two weeks the cast is changed and a new wedge cast is applied. The average period of casting is eight weeks.

Correction of Severe or Neglected Equinovarus

Davis, in 1892, described a wedge-shaped resection of the mid tarsal area to correct old varus deformities. The operation consisted of removal of a section of bone from the mid tarsus, the anterior segment of the wedge being taken from the cuboid and the posterior portion of the cuneiform bones, and the posterior cut being made through the anterior portion of the os calcis and neck of the astragalus. This procedure is still incorporated in the majority of technics to correct an old varus deformity of the foot.

Many corrective operations have been devised for deformities observed in patients eight years of age and beyond A combination of methods is usually employed, as follows

Technic—The inner aspect of the foot is incised parallel to the lower border of the os calcis. The attachments of the plantar fascia and short flexors of the toes on the inferior aspect of the os calcis are stripped free, after the manner of *Steindler (p 1298)* or by subcutaneous division (p 1297) The foot is then forcibly overcorrected with the aid of a Thomas wrench or wedge-shaped block. If correction of the varus or cavus is inadequate, the mid tarsus and subastragalar joints are next exposed by the anterolateral (p 138) or Kocher incision (p 137) preferably the former A cuneiform osteotomy is carried out through the mid tarsal region, the *base of the resected wedge* being laterally and the mid tarsal joints being included in the mass. The

amount of bone excised must be adequate to correct fully the varus deformity The foot is placed in normal alignment

The subastragalar joint is next exposed through the same incision and a wedge-shaped section of bone is again excised The base of this wedge should be on the lateral side of the joint Sufficient bone should be removed to correct the inversion of the os calcis and place the bone in a weight bearing position beneath the astragalus.

Finally after the tendo achillis is lengthened by a Z-plastic method (p 328) and the posterior capsule is incised transversely, particularly on the medial side the equinus deformity is corrected by manual force

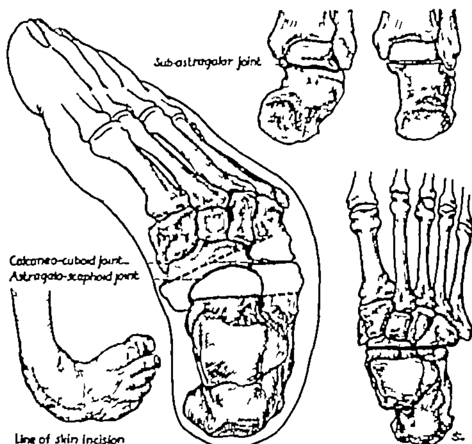


Fig 1087.—Operation for neglected equinovarus deformity Shaded areas indicate amount of bone removed from midtarsal region and subastragalar joint in moderate, fixed deformity In severe deformity the midtarsal wedge may include even a portion of the cuneiform bones and a larger portion of the astragalus and os calcis.

In extreme equinovarus deformity in adults, even more radical excision of bone may be necessary to complete correction of the varus deformity of the foot and inversion of the heel. The wedge-shaped section from the mid tarsus may include the anterior section of the astragalus and os calcis, the entire scaphoid and the major portion of the cuboid and lateral cuneiform bones. Extensive resection of the superior surface of the os calcis and inferior portion of the astragalus, or complete removal of the astragalus, may be required before alignment and position of the foot are satisfactory

After Treatment.—The foot is placed in a plaster cast from the toes to just below the knee During this procedure one must exercise care to avoid producing an osseous protuberance on the sole of the foot, or a rocker bottom foot. After three or four weeks the cast is removed and the slightest deformity of the foot is corrected Fixation is then continued by a walking

cast extending from the toes to the knee and walking is permitted with the aid of crutches. At the end of eight to twelve weeks postoperatively a free motion ankle brace is fitted, a T strap is placed on the shoe, and the outer sole of the shoe is elevated, or a leather leg and ankle corset is applied. Generally all apparatus may be discarded after six months, although this will depend upon the degree of osseous union of the severed bones. In every case the foot must be observed for a period of two years after correction.



Fig. 1088.—Severe neglected equinovarus deformity in adult, before and after correction.

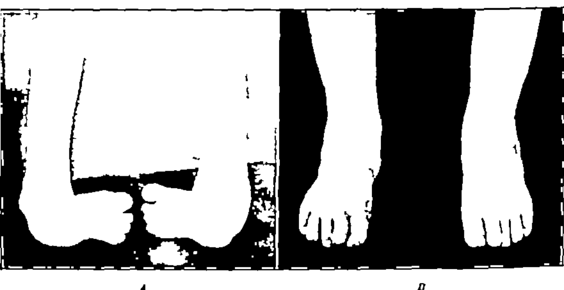


Fig. 1089.—A Extreme clubfoot deformity B Excellent correction of deformity by tarsal reconstruction.

The younger the child at the time of correction of the deformity the more resilient and normal will the foot be when full growth is attained. Following early treatment, moreover the soft structures, particularly the gastrocnemius and soleus muscles, develop until the contour of the leg approaches normal. In neglected cases, the deformity may be corrected, yet relatively little motion of the tarsal joints will be conserved and as a consequence the gait will be inelastic In adults with extreme deformity a large mass of bone must be removed the corrected foot will therefore be much smaller than normal, although function will be improved materially and ordinary shoes may be worn.

CONGENITAL ABSENCE OF A LONG BONE

Total or partial absence of a long bone calls for plastic operations to restore as nearly as possible the normal structure and function of the part In some cases, bones may be replaced with a fair functional and cosmetic result, whereas in others only a stump for an artificial limb can be secured

ABSENCE OF THE TIBIA

In absence of the tibia, the affected leg is much smaller and shorter than the normal one the difference being caused not only by shortening of the fibula, but by displacement of its proximal end, which lies on the lateral side of the external condyle of the femur The lower end articulates with the lateral side of the posterior tarsus. The foot, as a rule is in severe equinovarus, and anomalies of the foot, as absence of one or more tarsal bones or toes, may be associated. The leg usually is adducted to an extreme degree on the thigh, and the fibula is bowed In early cases, alignment of the extremity may be secured by manual force The bowing of the fibula should not be corrected until after one or both ends are firmly anchored In resistant deformities of the foot correction is carried out by successive wedging casts.

Surgery is not advisable until the child reaches the age of six months. Some writers believe that operative measures should not be undertaken until the child is two years of age in our opinion however the earlier the fibula can be placed below the femur the better the functional adaptation Amputation at this age should not be considered as artificial limbs are unsatisfactory in growing children Further, by reestablishing the continuity of osseous support and thus affording active use of the member shortening and atrophy may be prevented to a relative degree or at least an extremity may be produced which will be satisfactory for a prosthesis after amputation when the patient reaches fifteen or sixteen years of age

Putti, in 1922, presented the following technic for repair of absence of the tibia. Osseous continuity of the extremity is restored by transference of the proximal end of the fibula into the intercondylar notch of the femur the distal end is fixed into the split superior surface of the astragalus, or if the latter is absent, into the os calcis. Finally the foot is aligned in the longitudinal axis of the leg i e., extreme equinus, and utilized to lengthen the extremity

Technic (Putti) —(First Stage.) An anterolateral incision is made from above the condyles of the femur obliquely to the lateral aspect of the leg ending at the middle and upper thirds. The capsule is incised exposing the lower femoral condyles. The capsular wall which is interposed between the femur and fibular epiphysis, is divided the biceps muscle detached from the head of the fibula, and the upper third of the bone mobilized During this process, the peroneal nerve should be isolated By abduction and flexion of the leg the upper end of the fibula is reduced into the intercondyloid fossa Because of shortening of the soft structures, complete extension of the knee usually is not feasible often an angle of only 140 to 150 degrees is possible.

Two courses are possible the fibula may be united to the scarified surface of the intercondylar notch with chromic catgut sutures, to form a synostosis, or a nearthrosis of the knee may be created by placing the head of the fibula in the intercondylar notch without disturbing the cartilaginous surfaces.

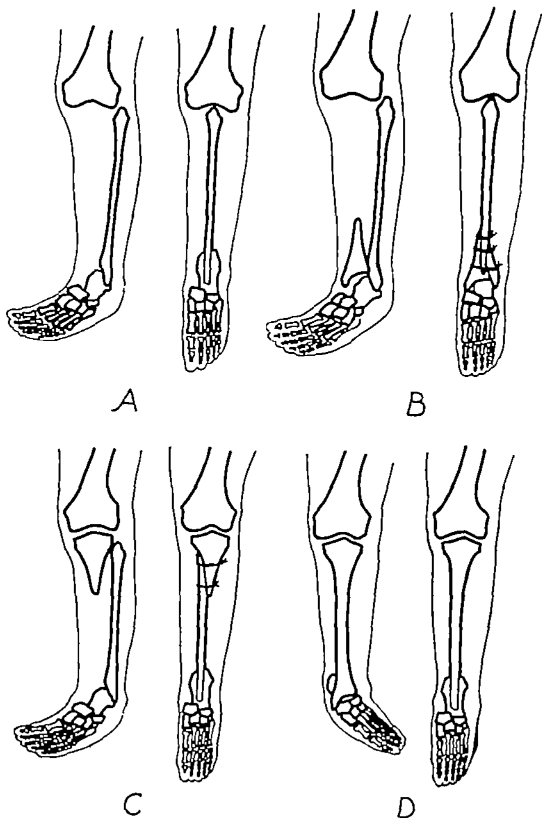


Fig. 1010.—Operations for congenital absence of tibia and fibula. (Putti) *A* Total absence of tibia. *B* Partial absence of tibia. *C* Partial absence of tibia. *D* Total absence of fibula. (From Putti, V Chir d. org. di movimento 18; 512 1929.)

After Treatment.—The extremity is immobilized in a plaster cast extending from the groin to the toes Successive casts applied once each month, may be required to extend the knee to 180 degrees and to correct the club foot. At the end of six months a leather lacer corset is fitted to the leg and foot holding the latter in extreme equinus An elevation is placed on the shoe to compensate for the two or three inches shortening and the child is taught to walk.

The second operation is carried out one year or more after the first This consists of transference of the lower extremity of the fibula into the astragalus. If desired the foot may be placed in extreme equinus to increase the length of the limb This throws the burden of weight almost entirely upon the metatarsal bones and toes, and in order to obtain the necessary support the toes must be brought into extension at right angles to the metatarsal bones by successive plaster casts.

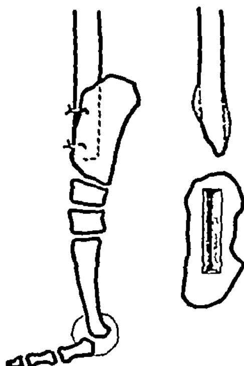


Fig. 1091.—Putti method of transplantation of fibula or tibia into os calcis with foot in extreme equinus, thereby gaining length, with weight bearing on heads of metatarsal bones.

Technic.—(Second Stage) The lower end of the fibula and its articulation with the tarsus are exposed through an anterolateral incision (p 147) the lower end of the fibula is mobilized and the foot maneuvered directly beneath the fibula. When alignment is obtained, the astragalus is split longitudinally with an osteotome or if this bone is absent the os calcis, forming a cleft into which the scarified distal extremity of the fibula is fixed with two chromic catgut sutures.

After Treatment.—A cast is applied from the groin to the toes, with the knee extended as far as possible and the foot in equinus. The cast is changed each month for three months A leather corset brace is then fitted and an elevation placed on the shoe.

After operation the fibula will hypertrophy to three or four times normal size and may even assume the shape of the tibia thus affording a fairly serviceable member Because of the excessive shortening however one can at best hope to provide only a poor substitute for a normal extremity

Should the flexion deformity of the knee persist, a *supracondylar osteotomy* of the femur (p 1033) or posterior capsulotomy of the knee (p 1030) may be carried out.

PARTIAL ABSENCE OF THE TIBIA

According to Putti, defects at either end of the tibia may be repaired after the manner described above for complete absence of the tibia If the proximal portion is absent (Putti has not observed such a case), the proximal end of the fibula may be transferred into the intercondylar notch. If the

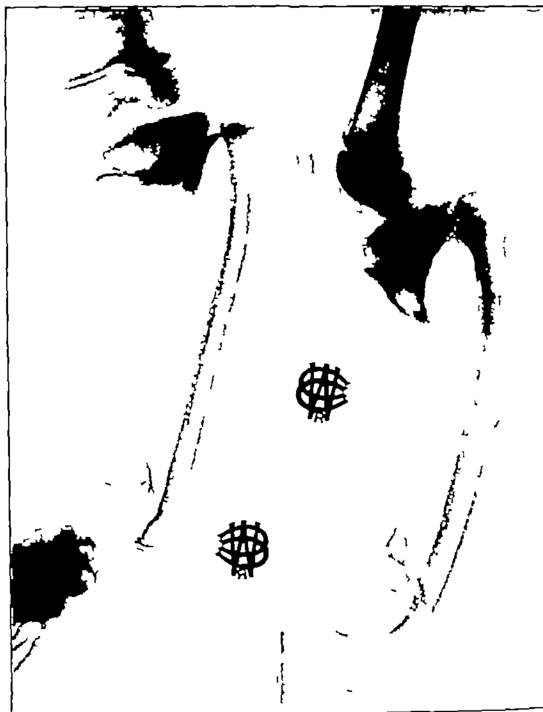


Fig 1082.—Defect of tibia from osteomyelitis.

distal epiphysis and metaphysis are not present the fibula is first grafted to the shaft of the tibia proximally then morticed into the tarsus at a second operation

ABSENCE OF THE FIBULA

In the absence of the fibula no operative measures are indicated until the patient attains almost full growth the most suitable age being sixteen to eighteen years. Meanwhile the foot which is in extreme valgus must be corrected by manual force and maintained in as nearly normal position as possible by appliances. Reconstruction of a new external malleolus by a free graft from the opposite tibia may then be undertaken

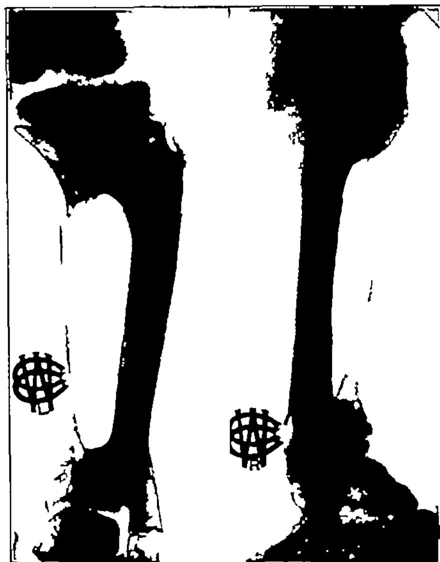


Fig. 1033.—Same as Fig. 109., after transference of fibula. (Same procedure might be applied to similar defect of congenital origin.) Note hypertrophy of transplant following active weight-bearing for two years.

Technic.—The ankle joint is approached through an anterolateral incision The tibia is exposed a distance of three inches, and a flat surface is created on its lateral aspect with an osteotome A free bone transplant three-fourths inch in width and four inches in length is then taken from the tibia (p 127) One end of the graft is fashioned into a cone shape, resembling the contour of a normal external malleolus, the endosteum is excised, and the massive plate of

cortex is approximated to the flat lateral surface of the tibia, the conical end protruding one inch below The graft is fixed into position by the screws, as described for the onlay graft (p 619) The endosteum is then divided into small pieces and placed about the graft in contact with the tibia.

After Treatment.—Immobilization is effected by a cast from the toes to the knee. At the end of two months a walking cast is applied and retained for one month The extremity is then fitted with a leather corset brace which is worn for a period of six months, or longer Corrective surgery for pes planus (p 1516) may be required later

The end results of this operation are relatively satisfactory The decrease in length may not exceed two inches, which is not sufficient to cause excessive disability If necessary blocking of the epiphyses of the opposite extremity (p 1440) at the age of ten to twelve years will compensate for the shortening

Putti in four cases, has corrected the associated valgus of the foot and fixed the tibia into the tarsus by a technic similar to that described on p 1573

ABSENCE OF THE FEMUR

Complete or partial absence of the femur is a more difficult problem being rarely if ever, amenable to surgery The operation if deemed advisable at all, must be planned according to the requirements of the individual case

ABSENCE OF THE RADIUS

Absence of the radius with excessive varus of the hand causes a condition known as club hand.' This, however is not analogous to clubfoot as usually the bones of the wrist or hand are not excessively deformed but are merely displaced toward the radial side of the wrist Operation is not advisable until the patient is two years of age as the arm is too small prior to that time.

Technic.—An incision is made in the midline over the dorsum of the wrist, from the base of the third metacarpal bone proximally a distance of three inches. The extensor tendons are separated by blunt dissection to expose the carpus. The medial aspect of the wrist is then incised in line with the ulna, and the soft tissue attachments at the distal end of this bone are freed by sharp dissection sufficiently to permit displacement of the ulna from the second into the first incision A cavity is excavated on the dorsum of the carpus in the midline and the distal end of the ulna is countersunk into this slot and fixed by No 1 chromic catgut sutures.

After Treatment.—The wrist is immobilized in a position midway between supination and pronation and in slight dorsiflexion. To prevent recurrence of *the deformity complete fixation must be continued for two or three years* by means of a leather lacer corset. Motion of the fingers should not be restricted on the other hand, free movements must be constantly encouraged.

The benefits of this operation are not brilliant, as there is always a conspicuous shortening The extremity never approaches normal.

Technic (Bardenheuer) —The distal end of the ulna is split into a radial and an ulnar portion and the carpal bones are allowed to slide between the separate ends in order to keep them apart. It is then secured in this position by a screw or wire loop

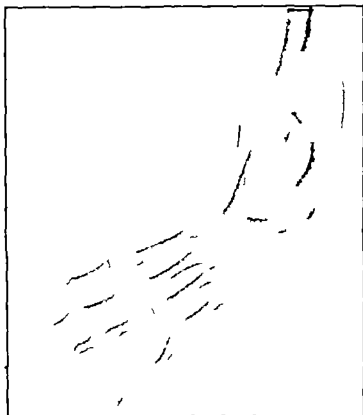


Fig. 1094.—Congenital absence of radius, treated by tranference of ulna, and tibial graft to small proximal remnant of radius.

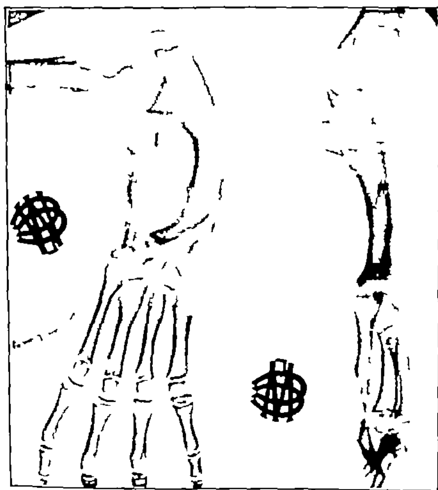


Fig. 1095.—Same as Fig. 1094. Six years postoperatively, forearm is still extremely short. Note that proximal radial epiphysis is active. Formation of medullary canal in transplant. Hand and wrist aligned satisfactorily with forearm.

Technic (Ryerson).—A bone graft is removed from the posterior surface of the ulna and transplanted beneath the extensors of the hand to the normal site of the radius. The periosteum as well as a portion of the distal epiphyseal cartilage is left attached to the graft with the view of aiding in the preservation of the osseous tissues after transplantion. The muscles and fascia are sutured over the newly formed radius.

Technic (Albee).—A cortical graft is taken from the tibia and each end is fashioned into wedge shape. The graft is then mortised into properly prepared orifices in the radial side of the carpus distally and in the ulna just proximal to the juncture of the middle and distal thirds. After the graft has thoroughly united with the bones at both ends, the deformity of the hand is corrected by an osteotomy through the ulna.

CONGENITAL DEFECTS OF THE LONG BONES

Procedures described for defects from other causes (Chapter XV) are also applicable to congenital defects of the long bones.

CONGENITAL DEFECTS OF THE MANDIBLE

Campbell has observed only one patient with a congenital defect of the mandible which necessitated surgery. The patient was nineteen years of age and considerable asymmetry of the face had developed, the mandible having deviated to the right side. Roentgenograms revealed complete absence of the condyle, ramus, angle, and basal portion of the body of the right mandible. A small remnant of bone was present along the external oblique line connecting the coronoid process with the alveolar portion of the body.

Technic (J. S. Speed).—The posterior portion of the seventh rib was removed with its articular processes, and the wound was closed. An incision was then made over the right jaw exposing the remnant of the mandible. This extended upward to a normal coronoid process, with normal muscle attachments. The previously removed rib was mortised into the outer aspect of the remnant anteriorly and the articular end inserted into the temporal joint. The transplant was held in place with two wire sutures.

Four months later the graft was firmly united to the mandible, the articulation was satisfactory and the biting strength of the jaw was good.

CONGENITAL PSEUDARTHROSIS OF THE TIBIA

Congenital pseudarthrosis is a specific clinical entity involving the lower half of the leg. Three types are recognized: (1) defect in the tibia at birth, (2) fracture associated with congenital cyst of the tibia, and (3) fracture associated with a congenital bowing of the tibia. In the latter group, the bone is usually small and sclerotic and the medullary canal is greatly diminished in size or is absent; such a bone may break as a result of minor traumata, or an injudicious attempt to correct the bowing by osteotomy may be followed by absorption and a typical pseudarthrosis.

From published data one may conclude that in no other condition is bony union so difficult to obtain; however, these published data also show that union is obtainable. The end results of surgical treatment are dependent upon the age of the patient and the efficiency of the surgical technic. The prospect of obtaining union becomes more favorable as the child grows older, particularly



Fig 1096.—Congenital defect of mandible. Reconstruction of body and ramus by transplantation of seventh rib. Articular process of rib utilized as condyle.

following puberty Camurati states that surgery should not be attempted in children under the age of six years. Henderson advises one well planned opperation in childhood and if this fails, the postponement of further surgery until puberty The longer operation is delayed however the more pronounced will be the shortening the leg will be more poorly developed and the deformity incident to the anterior bowing of the leg and the calcaneovalgus of the foot will increase. When union is obtained in a young child, function and weight bearing during the growth period predispose a more normal development.

If one wishes to postpone surgery because of the age of the patient, the lower extremity should be fitted with a leather lacer brace to support the leg, and to prevent the increase in deformity The most advantageous age for operation is difficult to determine We would agree however that it is probably wise to postpone surgery until the child is five or six years of age. If the surgeon has the cooperation of the parents, the use of a proper brace until this age will tend to minimize the deformity

In addition to bone-grafting procedures one has another alternative amputation. The function of the extremity which may reasonably be expected following a successful bone graft must be compared with that of an artificial limb rather than with the function of a normal extremity An expected shortening of more than three inches a considerable residual deformity such as anterior bowing of the tibia and pes calcaneovalgus and the constant possibility of refracture of a small weak tibia may be indications for an amputation. On the other hand in some patients a bone graft is undoubtedly preferable. One of our patients is now twenty four years of age has completed three years of nurses' training is married and has a child, and is doing her own housework. Certainly in her case the bone grafting procedure was worth while.

Many types of operations have been recommended Incision through or osteotomy of the pseudarthrosis followed by manipulation and immobilization in a cast may assist in the correction of deformity but is of no value in securing union

Excision of the pseudarthrosis, with exposure of normal bone on each fragment, followed by apposition of the fragments with sutures and external immobilization has been followed by union in comparatively few cases. This procedure also necessitates wide resection of bone and adds to the shortening of the extremity

Hallock has used multiple bone chips to fill a gutter extending across the pseudarthrosis and into normal bone in each fragment. His results have been good. The small multiple grafts are excellent for promoting osteogenesis, though internal fixation is not obtained.

McFarland has described an ingenious by pass ' bone graft no attempt is made to correct the deformity He reports two cases in both of which union took place The graft is completely surrounded by soft tissue which may be a theoretical disadvantage

Wilson has employed a two-stage transplantation of the fibula into the tibia in five cases. This procedure may not be applicable in that a coexisting congenital defect of the fibula frequently accompanies a pseudarthrosis of the tibia. We feel that the fibula should be preserved intact since it adds considerable strength and support to a tibia which, after bone grafting may at best be rather fragile and susceptible to the possibility of subsequent fracture.

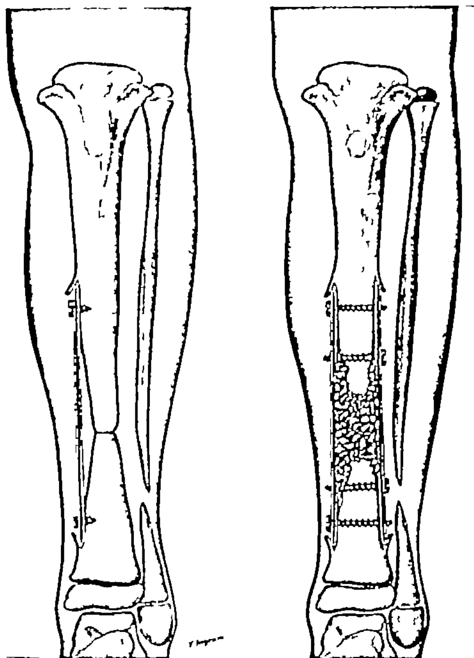


Fig. 1097.—Boyd dual graft for congenital pseudarthrosis. *A* First graft is held in position temporarily by two short screws. *B* Subsequently both grafts are fixed in position by screws which pass through both grafts and intervening bone. Temporary screws have been removed and replaced by permanent screws. Trough filled with cancellous bone. (From Boyd, H. B. J Bone & Joint Surg 23: 497 1941.)

The massive onlay bone graft has been the operation of choice in this clinic and has been fairly successful. Experience has demonstrated that the best results from the treatment of ordinary nonunions follow the use of the technic described by Henderson and Campbell Two principles are employed in each of these procedures secure internal fixation is obtained by means of a cortical tibial graft, and osteogenesis is promoted by cancellous bone packed about the fracture site



Fig 1098.—Congenital pseudarthrosis in patient aged 27 months.

In congenital pseudarthrosis, union is more difficult to secure than following nonunion of traumatic fractures. It would seem, therefore that more effective bone grafts are necessary in the treatment of congenital pseudarthrosis than in patients with ordinary nonunions. With this in view Boyd developed the dual bone graft technic described below The advantages of this technic over the single onlay bone graft are as follows (1) Better mechanical fixation is obtained (2) the tibial grafts provide rigid internal fixation over a long period of time (3) Cancellous bone placed in the trough between the two grafts is revascularized quickly and produces a fairly reliable osteogenic element (4) With a dual graft, the clamplike action of the two grafts compresses the osteoporotic tibial fragments. With a single graft, the screws may

fail to hold in the host bone (5) The grafts prevent compression of the cancellous bone by contracting fibrous tissue during the healing process thus minimizing the hemi hourglass constriction of the bone at the fracture site (6) The diameter of the host bone is increased by the grafts (7) Partial absorption of one graft does not necessarily result in refracture and failure

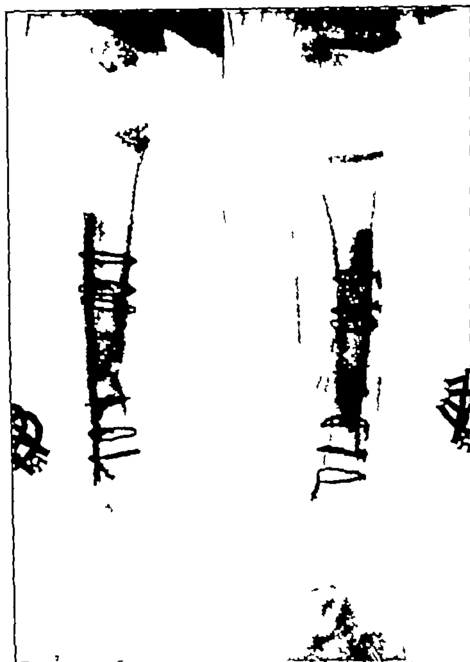


Fig. 1039.—Same as Fig. 1038 two months after onlay bone graft. Graft removed from tibia of mother

At operation, the surgeon should remember that the bone is small and osteoporotic Since the dual grafts form a bone clamp the ossifying bone is easily fractured just above the ankle at the lower end of the graft. This occurred in two of Boyd's cases. In both however the fracture united promptly In one case bilateral supramalleolar osteotomies were performed to correct valgus of the ankles. These osteotomies united in normal time. This confirms our opinion that the cause for nonunion in congenital pseud

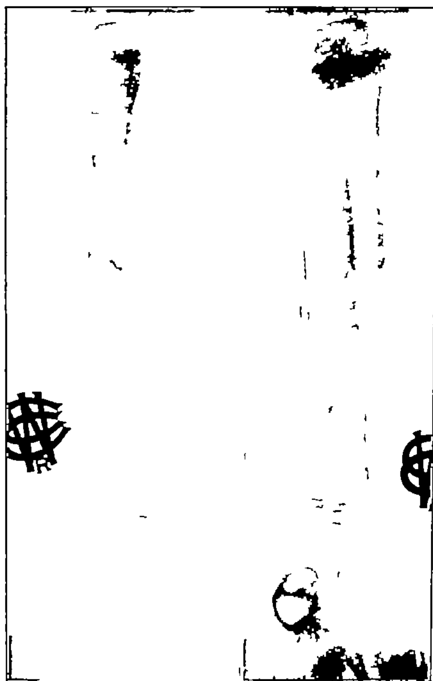


Fig. 1100.—Same as Fig. 1098. One year after operation.

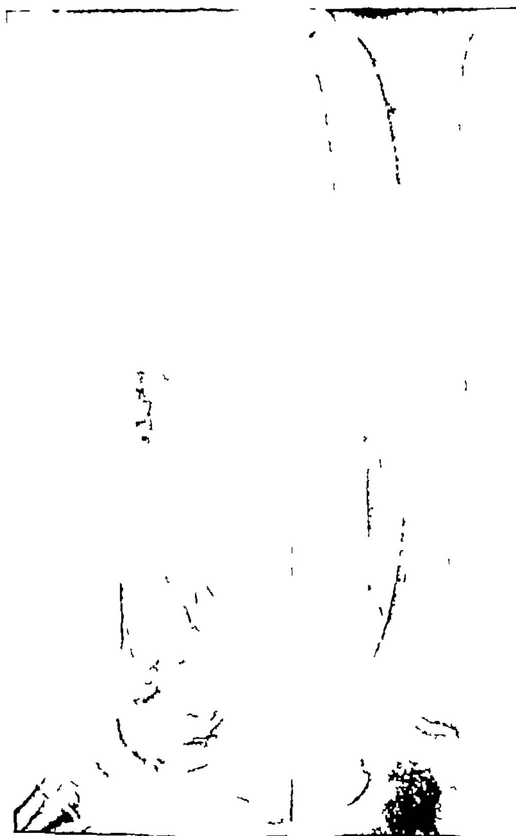


Fig. 1101.—Same as Fig. 1098 Twenty two years following operation.

arthrosis is entirely localized does not involve the other bones of the bo
nor even the same bone a few centimeters removed from the pathologic area

Heretofore syngenesioplastic grafts have been utilized. In the futu
grafts taken from a bone bank may be ideal for this procedure.

Dual Onlay Bone Graft (Boyd).—Two tibial cortical grafts, 4½ incl
long and ¾ inch wide, are prepared by removal of the endosteal bone. .
ample supply of additional cancellous bone must be available



Fig. 1102.—*A* Congenital pseudarthrosis in patient aged 7 years. *B* One month follow
initial dual graft.

The pseudarthrosis is exposed through a long anterior incision, and sc
tissue forming the pseudarthrosis is excised Eburnated bone which cove
the ends of the fragments is removed, with care to preserve as much leg leng
as possible The medullary canal of each fragment is then opened with a dri
In order to correct the anterior bowing lengthening of the tendo achil
through an additional incision (p 1021) may be required Unless the fibu
also contains a defect, it may be necessary to osteotomize this bone

A bed is prepared for the grafts on the medial and lateral surfaces of bo
fragments of the tibia A sufficient amount of bone is shaved from each si

to insure a denuded area for the grafts and to form a flat surface for maximum contact The amount of bone removed from the expanded area of the tibia is larger at a distance from the pseudarthrosis, than in the immediate region of the pseudarthrosis Considerable space may remain between the grafts at the fracture site especially if the ends of the fragments are conical This is not a disadvantage if the space is filled with cancellous bone

The graft should extend as far down the tibia as possible without violating the lower tibial epiphysis and for an equal distance proximally The longer the graft the better in small children it may extend to the upper tibial metaphysis

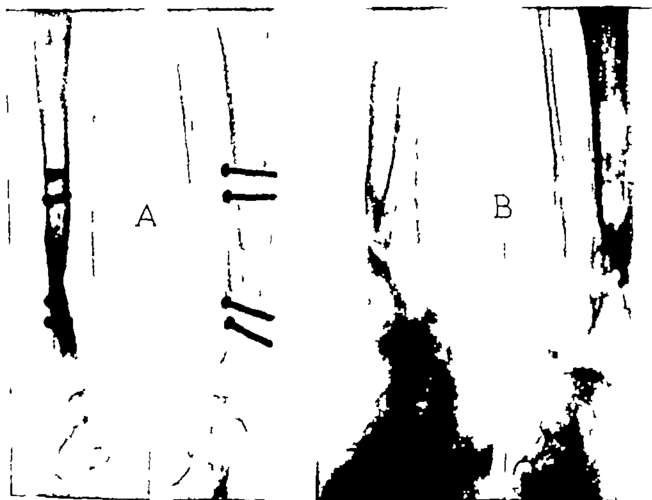


Fig 1163.—Same as Fig. 1162. *A* Six and one-half months following dual bone graft. Beginning crack in tibia just above proximal screw in distal fragment. *B* This amount of absorption has taken place at fracture site within three months.

One graft is placed on the inner or outer surface of the tibia and held by two short, temporary screws The second graft is then applied on the opposite side and the two grafts are fixed in the cortices of the host bone by two long screws. The shorter screws are then removed, one at a time and replaced by long screws passed through both grafts and the intervening bone The screws should be placed as far from the area of pseudarthrosis as is practicable as their presence is likely to predispose a subsequent fracture

The trough formed by the two grafts and the space about the pseudarthrosis are packed with cancellous bone The entire space both posterior and anterior to the pseudarthrosis should be eradicated. This is an important step in the operation as cancellous bone is essential to union Only the

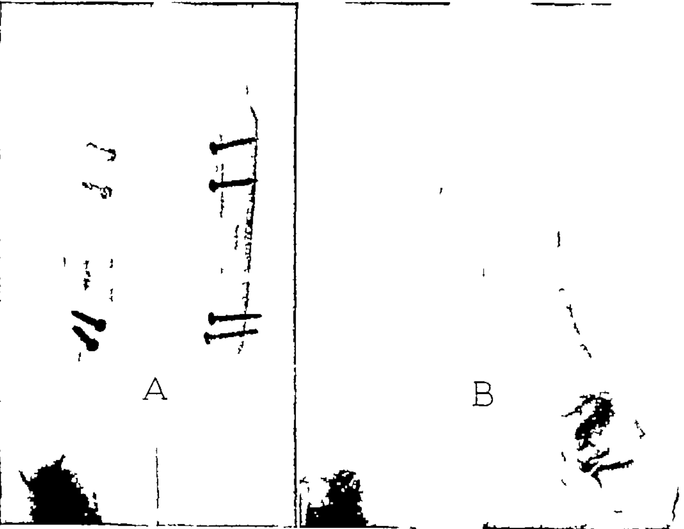


Fig. 1104.—Same as Fig. 1102. *A*, Appearance of tibia soon after second dual graft. *B*, Three years following second dual graft.

skin and subcutaneous tissues are closed with interrupted silk sutures, no effort is made to close the deep fascia as sufficient soft tissue is not available after the cubic contents of the leg are increased by the dual grafts

After Treatment.—A long leg cast is applied, or in small fat children, a spica cast may be necessary to insure adequate immobilization The cast is usually changed after ten days or two weeks, and replaced by one which fits snugly The cast should be changed as often as necessary to insure firm immobilization until union is apparent in the roentgenograms This usually requires from four to six months Following cast immobilization, a leather lacer brace is fitted to be worn until a well developed medullary canal has formed and the affected tibia is of essentially normal size Usually, the use of a brace is necessary until puberty The type of brace advocated by Kite wherein the leather sleeve laces posteriorly is superior to those laced down the front of the leg With this apparatus a solid well molded piece of leather on the anterior surface of the leg affords better support to the tibia, as a rule the tibia tends to angulate in an anterior direction

Boyd has found that fracture is likely following bony union, and that if fracture occurs a condition similar to the original pseudarthrosis quickly develops at the fracture site The cause of the rapid absorption of bone about the fracture site is not known In the patients reoperated upon for fractures following union the tissue has been carefully examined for neurofibromata, though none were found Union following a fracture is apparently as difficult to obtain as in the original nonunion with the exception that the patient is older and the older the child, the better the prognosis

In one of Boyd's cases an insufficiency ' or so-called "March fracture" gradually developed at the original site of pseudarthrosis years after bony union had occurred The gradually developing fracture differed from a March fracture in that no callus formed about the fracture site. The insufficiency fracture weakened the bone to such an extent that a minor trauma even while wearing a brace produced a complete fracture of the tibia and pseudarthrosis followed

In view of the tendency toward fracture, it is essential that adequate bracing be carried out as described above The surgeon should watch for evidence of an early insufficiency fracture recurrent sclerosis about the old fracture site or narrowing of a previously formed medullary canal In the presence of one or a combination of these findings an operation to reinforce the area of former pseudarthrosis with supplementary grafts may be indicated before the tibia completely fractures Although Boyd has not utilized this procedure he believes it would be advisable in the future

In seven cases which Boyd has reported ten massive bone grafts have been performed Bony union followed in all but one of these which indicates that union may be anticipated in the majority of cases following an efficient operation In three cases however fracture occurred following union. Details of these seven cases are as follows

CASE	OPERATION	REFRACTURE	RESULT
1	27 mo.	No	Union 2½ yr
2	4 yr	5 yr 8 mo.	Union 1 yr 9 mo
3	5 yr	No	Union 2 yr 7 mo.
4	7 yr	No	Union 7 yr 4 mo
5	6 yr	4 yr 11 mo.	Amputation
6	7½ yr	6½ mo.	Union 3½ yr
7	(yr failure re grafted	No	Union 1½ yr

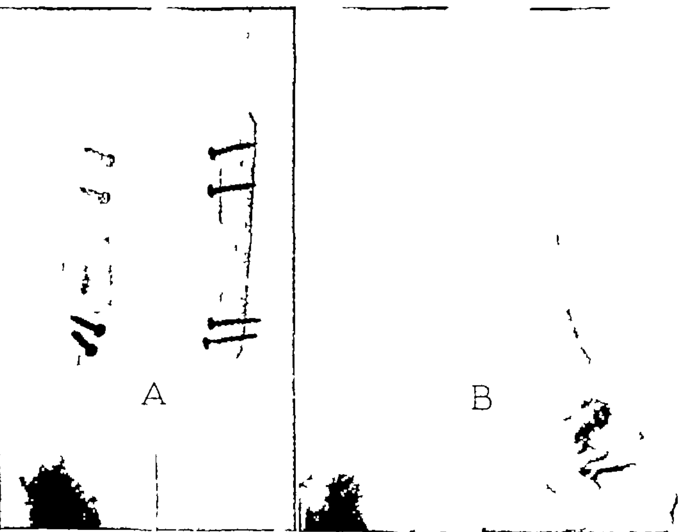


Fig. 1104.—Same as Fig. 1102. A, Appearance of tibia soon after second dual graft. B, Three years following second dual graft.

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CASE	OPERATION	REFRACTURE	RESULT
1	27 mo.	No	Union 22 yr
2	4 yr	5 yr 8 mo.	Union 1 yr 9 mo.
3	5 yr	No	Union 2 yr 7 mo.
4	7 yr	No	Union 7 yr 4 mo.
5	5 yr	4 yr 11 mo.	Amputation
6	7½ yr	6½ mo	Union 3½ yr
7	7 yr failure regrafted	No	Union 1½ yr

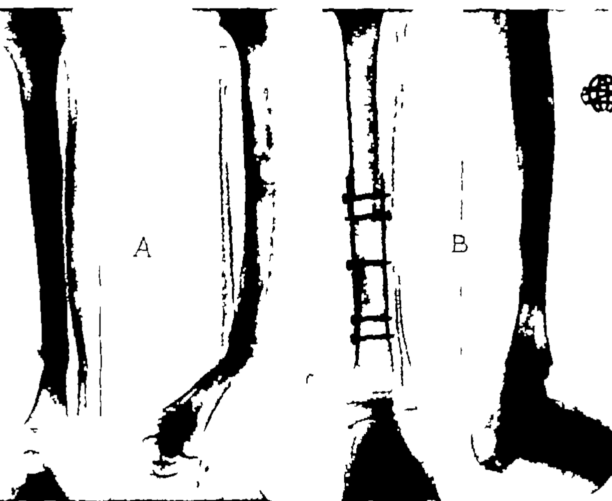


Fig 1103.—A Congenital pseudarthrosis in patient aged 7 years. B Four months following dual bone grafting.

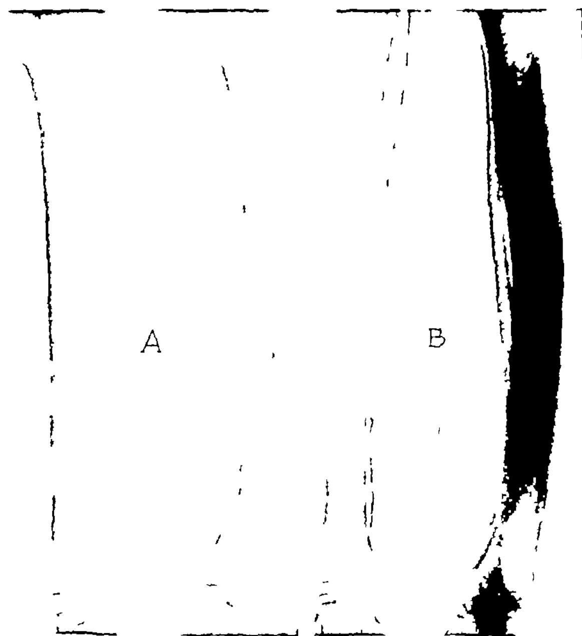


Fig. 1166.—Same as Fig. 110 *A* Four years and *B* 7 years, respectively after dual graft.

Hallock points out that the smaller the bone transplant, the more quickly will its replacement be effective. He has devised the following technic for congenital pseudarthrosis

Technic (Hallock).—The area of pseudarthrosis is exposed by subperiosteal dissection. This should be limited to the minimum requirement. The ends of the fragments are freshened and resected sufficiently to permit correction of the deformity and end-to-end apposition. A broad shallow groove is made in both fragments, extending from good bone in the upper fragment to good bone in the lower This groove opens into the marrow cavity and provides a wide area of traumatized bone for stimulation of granulation tissue growth for contact with multiple grafts. The groove is then filled with many small bone transplants or chips taken from the opposite tibia or preferably from the ilium The periosteum is closed with interrupted sutures so spaced as to leave intervening gaps through which the blood vessels and granulation tissue can grow into the area of bone formation from the traumatized soft tissues at the periphery

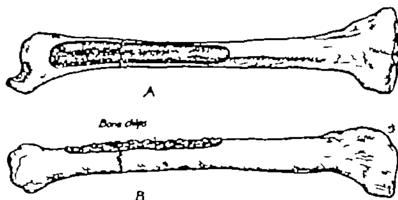


Fig. 1107.—Hallock operation for congenital pseudarthrosis. *A* Fractured surfaces freshened, placed in anatomic alignment, and trough created in both fragments. *B* Trough filled with multiple small bone chips from opposite tibia or from ilium.

After Treatment.—The extremity is immobilized in a cast and so maintained for ten to twelve weeks. Walking is then instituted by means of a walking cast, which is worn until the roentgenogram demonstrates normally formed bone strong enough to function without support

Of seven pseudarthroses in five patients, Hallock secured solid union in six Ten operations were required for the six successful unions. Even so this is an excellent percentage. The ages of these patients were four and one-half, nine two and one half three and one-half, and three years.

CONGENITAL GENU RECURVATUM

In congenital genu recurvatum the quadriceps muscles and tendon, and the patellar tendon are shortened Lengthening of these structures may be effected by gradual stretching if begun sufficiently early This method should always be employed in children under two years of age. In more resistant or neglected cases, operation is advisable.

Technic.—The quadriceps tendon, patella and patellar tendon are exposed by an anteromedial incision (p 140) The quadriceps tendon is elongated by Z-plastic division, and the knee is carried to the limit of flexion. Adhesions or bands, if present, are severed.

After Treatment.—By means of a splint the knee is maintained in 90 degrees' flexion for a period of eight weeks. Physical therapy is then instituted. At this time also, a brace is applied with a stop joint at the knee to prevent extension beyond 175 degrees. The brace should be worn for a period of one year or more.

Recurrence of the deformity is common. Contour of the joint surfaces remains abnormal, and, as a rule, motion is limited.

CONGENITAL DISLOCATION OF THE KNEE

In this dislocation the tibia is practically always displaced anteriorly and often there is an associated genu recurvatum. The operation for correction, which should be carried out before the patient reaches the age of two years, is similar to that for genu recurvatum; however, the anterior structures over the extremities of the femur and tibia must be more widely dissected so that the normal articulation may be restored. Apposition is maintained with difficulty, as the contours of the bones are extremely distorted, the articular surfaces do not conform, and one must rely upon external apparatus.

After Treatment.—A cast is applied, holding the knee in 150 degrees flexion. After eight weeks, the cast is removed, roentgenograms are made to confirm the proper alignment, and measurements are taken for a brace with a stop joint at the knee to prevent hyperextension. The cast is then replaced and worn for an additional four weeks. At the end of this period the brace is applied and worn for one year.

Because of the irregularity of the articular surfaces, ultimate function is only fair compared to that of a normal joint and is by no means comparable to the result secured in congenital dislocation of the hip joint. Reconstruction or fusion may be necessary after full growth is attained.

CONGENITAL DISLOCATION OF THE PATELLA

Congenital dislocation of the patella should be distinguished from the acquired type of lateral displacement of the patella. The anomalies associated with the congenital type are not seen in the acquired type. There is usually a familial history. Mumford reported a case in which the condition was present in four successive generations. Usually the anomalies are not confined to the patella itself but involve the other components of the knee joints as well, viz., the patellar tendon, the quadriceps mechanism, and the lower end of the femur.

In 1925 Conn presented an excellent treatise on congenital luxation of the patella and described a new method of operative reduction.

Technic (Conn).—Abduction and rotation of the tibia, if present, is corrected first. This can usually be accomplished by the application of successive plaster casts, correction being increased with each application.

A U-shaped incision with its convexity downward is made through the skin; the outer limb is carried well back over the external lateral surface and well upward. The flap is reflected upward, exposing the knee capsule. The patella is small and its articular surface is opposed to the lateral surface of the femoral condyle, being anchored in this position by the shortened fibers of the capsule. The quadriceps tendon is usually well developed, the vastus internus elongated and stretched, and the vastus externus shortened and displaced backward.

The tendinous attachments of both vasti are freed from the quadriceps tendon proper and reflected upward later to be reattached in another position. A longitudinal incision of ample length is made external to the patella through the capsule and synovia which allows the patella to be *pushed into* the midline. This leaves a diamond-shaped gap The contour of this gap is traced out and cut from a piece of tin foil A piece of similar shape is then cut from the medial capsule and synovia transferred to the lateral defect and sutured in place the suture being placed in the capsule only The gap on the medial side is similarly sutured The elongated fibers of the vastus internus is *then shortened and the cut sutured under slight tension to the* quadriceps and patella The reflected and already shortened vastus externus is reattached without lengthening to the quadriceps tendon about one inch higher than the center of the attachment of the vastus externus. The outer flaring quadriceps fibers are cut across about one-third of their breadth and the lower cut fringe is folded under the unsevered portion of the tendon, and secured in place by mattress sutures. The wound is closed in layers

After Treatment.—A light cast is applied with the knee flexed just enough to secure slight tension of the quadriceps. The cast is removed in two weeks and an elastic bandage applied. Weight bearing is allowed in three weeks and full use encouraged during the fourth week

McCarroll and Schwartzmann describe an operation which is applicable to the acquired *or congenital dislocation of the patella* It is a *combination* of the technic of Hauser (p 313) and a modified Robertson operation the semi tendinosus tendon is given a bony insertion into the patella rather than into the patellar tendon

CONGENITAL DISLOCATION OF THE HIP

Some knowledge of the anatomy of this anomaly is essential to the proper understanding of the causes of failure and success of the treatment. This phase of the problem therefore will be discussed in brief.

Congenital dislocation of the hip arises from a lack of embryonic development of the joint. Since the osseous changes as demonstrated by the roentgenogram are not conspicuous at birth, diagnosis is exceedingly difficult. As growth progresses, however the status of the structures becomes apparent. A brief summary of the changes present after the lapse of three or four years is as follows

1 The acetabulum is shallow triangular in shape and may be filled with cartilaginous or fibrous tissue.

2 The head of the femur is poorly developed irregular and small, and in comparison, the neck is thick and short

3 Anterior torsion of the neck of the femur may be 45 degrees or more at birth in contrast to the normal 35 degrees. Further rather than decrease as it normally should the torsion may increase with growth after three or four years approaching 90 degrees and causing the flat surface of the neck to come in contact with the pelvis.

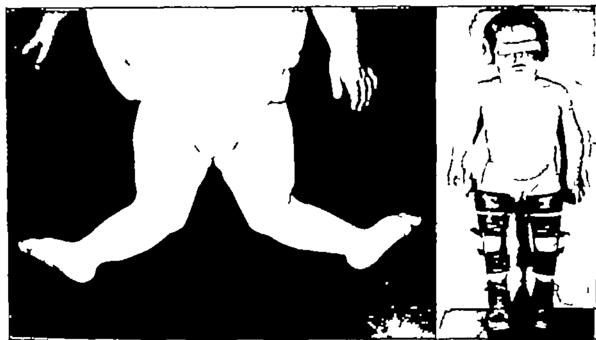
4. The capsule, in particular is abnormal, being extremely thick, and perhaps ending at the epiphyseal line rather than laterally on the neck. Its posterior superior surface is usually adherent to the ilium. An hourglass contracture. or a fold of the thickened inferior capsule, together with the superior rim of the acetabulum may form an insurmountable barrier to closed reduction. On reduction the inferior fold may precede the head into the

acetabulum and cause recurrence of the dislocation when the hip is brought down from extreme abduction In many closed reductions, the head must erode through the inferior fold before complete articulation is possible

5 The ligamentum teres may be elongated and thickened, or, rarely, may be entirely absent

6 The abductor muscles are shortened and unable to function as the trochanter is high on the ilium This loss of gluteal muscle power and the loss of bony support to the head of the femur are responsible for a positive Trendelenburg sign

7 The soft tissues which pass from the pelvis to the thigh particularly the hamstring and adductor muscles, are contracted



A B.

Fig. 1108.—A Congenital dislocation of both knees treated by open reduction. Patient also had open reduction and shelf operation for congenital dislocation of right hip. Dislocation of left hip treated conservatively B Patient at age of three years. Tendency toward valgus deformity controlled by braces. Patient aged seven years at last visit both hips stable, excellent result in right knee with 70 degrees' motion slight instability in left knee, with 90 degrees' motion walks one and a half miles to school daily without braces or crutches.

8. Three distinct types of dislocation can be recognized and differentiated the posterior dislocation the upward subluxation, and the anterior dislocation. Cases of the last have been reported by various authors but its significance has never been adequately stressed McCarroll and Crego report ten cases of true primary congenital anterior dislocation of the hip Howorth feels that practically all of the congenital dislocations of the hip are anterior that the posterior dislocation is simply a transition from a primary anterosuperior dislocation As the capsule elongates, the head displaces upward and backward on the ilium being limited anteriorly by the tendons attached to the spines of the ilium.

In 185 open operations studied by Howorth the femoral head was almost invariably dislocated outward upward and forward. He feels that the higher percentage of posterior dislocations reported by other authors may be due to a larger number of older cases.

The earlier reduction is effected, the sooner will functional adaptation restore an anatomy which approaches normal and permit a commensurately normal degree of function

The corrective measures for congenital dislocation of the hip may be classified as follows

Closed Methods

1 Closed reduction
2. Manual osteoclasis for correction of anteversion

Open Operations

1 Open reduction
2 Osteotomy for correction of anteversion
3 Shelf operations
4 Lorenz osteotomy
5 *Schanz osteotomy*
6 Osteotomy and open reduction

In children less than three years of age reduction of the dislocation by manual force is now generally regarded as advisable when this can be effected without undue trauma. Since the degree of abnormality varies in different patients at any given age there is of course no arbitrary age limit at which surgery is indicated in preference to conservative measures. In general, however surgical correction is the treatment of choice in patients over three years of age and may be undertaken prior to that time if manual force fails or the dislocation recurs Some surgeons as Galloway advise open reduction in all cases. Others state that closed reduction suffices in patients under six years of age

In any event, if excessive force is used in either open or closed reduction, the damage to the femoral epiphysis, by direct trauma or interference with the circulation, will lead to shortening of the extremity and material impairment of function when full growth is attained.

In bilateral dislocations the treatment described is carried out on both hips. The results are less successful however than when the dislocation is unilateral

Closed Reduction

The measures first employed in the treatment of congenital dislocation of the hip were closed manual reductions. Paci described a closed method in 1888 this was later popularized and the after treatment was improved by Lorenz. Others who played an important part in devising technics for forcible correction were Ridlon Davis, Calot, Denucé, Fritz Lange, Bradford Hibbs and others.

Putti reports that 95 per cent of his patients in whom the dislocation was discovered before they reached the age of twelve months obtained a successful result merely by maintenance of the hip in abduction and internal rotation. Thus, a careful examination including roentgenographic studies of every infant, and the institution of early treatment would go far to solve this problem. In some countries, such measures are practicable and justifiable, but where the condition is rare as in the United States they are hardly warranted because of the time and expense involved. In this country the condition is seldom discovered or the child presented for treatment until walking is begun.

Technic (Lorenz)—The child is given a general anesthetic and placed on a hard surface The hip is flexed to 90 degrees, abducted as far as possible and rotated outward to stretch the adductor muscles. These structures are kneaded or massaged rather vigorously with the ulnar border of the hand to strip loose their attachments to the pelvis. Should this not succeed as frequently happens in older children, the adductor muscles are severed subcutaneously The hip is next abducted as far as possible to stretch the anterior capsule and soft structures With the hip and knee flexed to a right angle reduction may be accomplished by placing a fulcrum just behind the greater trochanter and gently abducting the hip the use of strong force should be avoided As the head of the bone is levered into the socket a definite click or snap can be felt Usually the outer border of the hand will serve as a fulcrum in resistant cases a padded wedge shaped block may be utilized



Fig. 1109—Frog-leg position maintained by cast after reduction of dislocation of hips.

Following this maneuver the head of the femur may be palpated in the socket at the approximate center of Poupart s ligament and tension of the hamstring muscles is adequate to maintain the knee in flexion of 90 to 150 degrees. This however is by no means a definite sign that reduction is complete but merely indicates that the position of the head has been changed to elongate the limb and stretch the soft structures. The head may be shown impinging on the pelvis near or on the rim of the acetabulum Reduction should always be confirmed by anteroposterior and lateral roentgenograms.

Lorenz advised gradual extension of the knee to stretch the shortened hamstring muscles This is not only unnecessary but is contraindicated, as the

tension of these muscles holds the head of the bone within the socket and will always relax later to permit full extension.

After Treatment.—By means of a plaster cast extending from below the knee to above the crest of the ilium, the hip is maintained in the position of flexion to 90 degrees, *extreme abduction and external rotation.* When the dislocation is unilateral the opposite limb is included in the first cast, in the same position. Subsequent casts are applied at intervals of two months for a period of eight to ten months, depending upon the development of the acetabulum To encourage functional adaptation Lorenz advised that the child be allowed to bear weight on the extremity as soon as possible, either by the aid of a kiddy car or by being held When the casts are discontinued physical therapy is instituted No force should be exerted to bring the hip down from the abducted position as this is best accomplished gradually by natural efforts of the patient

Surgeons differ in their methods of after treatment of congenital dislocation of the hip both as to position and the period of immobilization Putti uses the classical Lorenz, or frog leg position which is 90 degrees abduction and 90 degrees' flexion In younger patients, this position is continued for only one and one-half to two months. The cast is then removed, and by *means of traction flexion is reduced to 135 degrees, abduction is diminished,* and the extremity is rotated internally to a slight degree If necessary three or four days may be allowed for this procedure The new position is maintained for a period of three to four months by another cast.

Lange concluded that because of torsion of the femoral neck, the hip should first be placed in hyperextension internal rotation, and abduction to approximately 135 degrees. According to the general opinion, this position, as a rule is employed following open reductions, or when closed reduction has been accomplished by traction with the hip in extension and internal rotation.

Mueller believes that since the capsule covers the shallow cavity leaving an entrance only in the posterior superior quadrant of the socket the primary position should be *right-angle abduction* with *internal rotation to such* a degree that the patella looks forward toward the frontal plane

Calot immobilizes the hip in flexion and different degrees of abduction and internal rotation, depending upon the angle of inclination of the neck and the amount of anterior torsion *His method of determining the angles of inclination and torsion is as follows* Under a fluoroscope, the femur is rotated until the maximum length of the neck is seen. The angle between the neck and shaft, or the angle of inclination, is then measured on the screen with a protractor As for the angle of torsion, the degree of internal rotation of the knee necessary to give the neck its maximum length is measured this rotation of the knee is equal to the angle of torsion of the neck of the femur Thus, for an angle of 180 degrees between the neck and shaft the thigh is placed in 90 degrees' abduction for 130 degrees, in 134 degrees' abduction and for 90 degrees, in 170 degrees abduction. For angles between these degrees, the abduction should vary commensurately Internal rotation of the hip should be equal to the angle of torsion of the superior extremity of the femur

Calot believes that in the first cast the hip should be immobilized in hyper flexion to allow the superior rim of the true acetabulum to hypertrophy and the retracted lower part of the capsule to be opened. Further this hyperflexion favors the correction of anteversion of the head Accordingly the hip is flexed on the abdomen to an angle of 45 degrees in the first cast in the second

cast flexion is decreased to 90 degrees, and in the third to 135 degrees The degree of flexion therefore, differs in the three casts though not abduction nor rotation The successive casts should each remain in place for a period of two months for children of more than five years of age, three months each for children from three and one half to five years, and three and one half months for those of less than three years of age

Werndorff employs a position which he calls "axillary abduction" when the hip is extremely unstable In this position the thigh is drawn up and extended along the lateral surface of the trunk until the knee is practically in the axilla This position is maintained for six to twelve weeks thereafter the treatment is continued according to the usual method

The routine after treatment described above by Putti is the shortest. *Other authors have advised maintenance of the Lorenz position for a period of* nine or ten months. In a compromise between these two we enforce the Lorenz position for three months the degree of abduction and flexion is then reduced the hip rotated internally and fixation continued for an additional four months.

The cast may consist of only a pelvic band extending to the knee on the affected side As a rule however the opposite extremity should be included in the cast until some degree of adaptation has occurred To encourage functional adaptation weight bearing may be allowed in the cast after the hip is brought into moderate abduction. Blount accomplishes this by means of a so-called peg leg cast the hip being held in the Lange position the cast is prolonged distally at the knee by means of a crutch incorporated in the cast, thus forming a weight bearing member

Technic (Ridlon) —The patient's hips are elevated four inches above the table on a sandbag and an assistant holds down the pelvis and thigh on the normal side When the left hip is dislocated the operator s left hand is placed in the patient's crotch the thumb being in front of the socket and the first, second and third finger tips on the femoral head, neck and greater trochanter The operator s right hand holds the thigh with the knee in flexion The hip is flexed bringing the head of the femur to the lower border of the acetabulum the thigh is then abducted slowly until the head glides into the socket. The cast is applied with the thigh flexed and abducted 90 degrees and rotated externally 135 degrees.

Technic (Denucé) —The adductor muscles are stretched manually by gentle massage with the palm of the operator s hand, beginning at the pelvis and continuing distally in the longitudinal axis of the thigh The thigh is gradually brought up to right angle flexion and full abduction and reduction is accomplished as follows The knee is carried across in the direction of the opposite axilla and the thigh is firmly placed on the anterior body wall. With the extremity held in this position by one hand the other hand is placed beneath the trochanter Circumduction is then begun the knee being carried across the trunk to its own side and into abduction while the trochanter is lifted upward

Fritz Lange has observed that the shortened muscles are the chief hindrance to reduction Instead of using forcible measures to stretch these contracted structures, he flexes the thigh to a right angle, thus relaxing the iliopsoas, rectus femoris, and tensor fasciae femoris muscles. The thigh is next adducted, relaxing the contracture of the shortened adductors. Finally, by flexion of the knee to an acute angle, the shortened hamstrings are relaxed.

With the extremity in this position, the head of the femur lies behind the posterior edge of the acetabulum Traction is then exerted on the thigh, bringing the hip into extension and abduction This is essentially the Lorenz technic without forcible maneuvers to stretch the contracted structures prior to reduction.

For older children a procedure based upon a different principle is employed by Lange reduction is accomplished by traction rather than by leverage, as follows

Technic (Fritz Lange) —With the hip in extension skin traction is instituted, 20 to 30 kg being utilized. After five to fifteen minutes, the trochanter on the affected side is drawn distally until level with the opposite trochanter At the same time the leg is placed in 135 degrees' abduction and rotated internally If some degree of lateral displacement of the head from the acetabulum persists, the head of the trochanter is pressed against the isthmus of the constricted capsule the action of the head resembles that of the bulb of a probe used in strictures of the esophagus. Soon, palpation reveals a bony resistance in the empty acetabular region.

Lange advises that, when reduction is accomplished by this method, a plaster cast should be applied with the hip completely extended and in extreme abduction and inward rotation while the knee is maintained in extension.

Technic (Davis) —The child is placed in the prone position on a well-padded table The hip and knee on the affected side are flexed until the knee lies against the side of the chest this brings the hip from a high position on the dorsum of the ilium into a low position. With the knee held firmly against the side of the chest downward thrusts are made on the trochanter with the heel of the hand stretching the adductor muscles. As this is accomplished, the perineum, which is elevated when the thigh is flexed, approaches the table. When all has been gained in this way that is possible an assistant places his doubled fist beneath the knee and raises the perineum sufficiently to permit further stretching The head thus slips from the posterior plane of the pelvis to the anterior plane The hip is gradually brought from the position of acute axillary flexion to a right angle flexion and abduction, firm pressure being maintained on the trochanter with the heel of the hand while this maneuver is carried out. As the thigh approaches a right angle, the head slips upward into the acetabulum.

Technic (Calot) —For the difficult cases continuous traction is maintained for several weeks, with the hip in extension. Reduction is carried out, the child being placed on the sound side and the pelvis held immobile by an assistant. The thigh is flexed to a right angle and the hip forcibly brought into adduction and internal rotation. An assistant then exerts traction in line with the thigh while the surgeon pushes the head toward the acetabulum with his thumbs. The thigh is next brought into abduction, completing the reduction.

Correction of Anteversion by Manual Osteoclasis

The majority of surgeons regard correction of anteversion of the neck necessary only in extreme cases growth and exercises will gradually accommodate for and overcome a moderate deformity In anteversion of 45 degrees or more, Howorth and Smith advocate either correction or a shelf operation.

For children under three years of age Krida advocates correction of ante version by manual osteoclasis, maintaining that infantile bony structure is frequently not sufficiently adaptable to insure correction of the structural twist of the femur before recurrence of the dislocation can take place

Technic (Krida) —After manual reduction the hip is immobilized in the Lorenz position and so maintained for two weeks. The cast is then removed and under anesthesia, the status of anteversion determined The head of the femur, if presenting superficially in the groin, does not come in contact with the acetabulum If upon lessening abduction to 150 degrees, the head becomes still more prominent or is displaced lateral to the line of the femoral artery, or if under these conditions, even slight outward rotation of the extremity displaces the head laterally, one may assume that a degree of anterior distortion of the upper end of the femur exists. If not corrected such a deformity will be inconsistent with the ultimate security of the hip The hip is then rotated internally to a degree sufficient to place the head in contact with the acetabulum With the hip abducted 150 degrees both hip and knee in slight flexion and the extremity rotated inward, a single spica cast is applied

After three months, the internal rotation which is of the same degree as the anteversion is corrected by a manual osteoclasis through the supracondylar region One hand holds the head and neck in the proper position while the other rotates the distal fragment externally A second single spica cast maintains this position for an additional two months.

Open Operations

Open operations may be divided into two groups those whereby a satisfactory anatomic and functional restoration or "cure" may be anticipated, and those which are palliative promising only an improvement in function.

No dogmatic statement can be advanced concerning the most appropriate surgical procedures, since the age of the patient the amount of deformity of the acetabulum the degree of anterior torsion of the neck, and other factors must be taken into consideration With the probability of numerous variations, therefore the following suggestions are offered If in children under three or four years of age, efforts to reduce the dislocation without undue force fail, open operation is indicated for removal of soft tissue barriers, reduction of the head into the acetabulum and plastic procedures on the capsule to lend stability When the acetabulum is shallow as is usual after the age of four years an added measure of stability must be supplied A plastic operation on the bone which compensates for the deficient rim of the acetabulum should fulfill this requirement

Gill delays the shelf operation until the patient has reached the age of five, and in the meantime maintains the limb by a plaster cast or brace to preserve the relation of the head of the femur to the socket. He believes that the failure of the operation before this age may be due to the fact that the acetabular roof is largely cartilaginous and the operative procedure damages its blood supply and prevents its conversion into bone

Ponseti feels that the shelf operation is indicated in children over four years of age if upon open reduction the acetabulum is found to be shallow as well as in patients with congenital or paralytic subluxation or with subluxation following an old reduced congenital dislocation when pain of static origin and a limp appears which is usually after puberty



Fig. 1110.—Congenital dislocation of hip in patient aged five years.



A B.

Fig. 1111.—Same as Fig. 1110. A After two weeks of skeletal traction. B After open redu

There is considerable diversity of opinion as to the proper procedure to be followed in patients between the ages of eight and fifteen years shortening is usually too great to permit reduction of the head into the original acetabulum If reduction is accomplished by means of skeletal traction and open operation alone recurrence of the dislocation is likely or, if maintained degenerative changes of the head will take place from the extreme pressure of the head against the acetabulum necessitating further surgery Putti believes that no surgery is advisable during this period After the age of fifteen years palliative measures, preferably the Lorenz or Schanz osteotomy, may be undertaken The shelf operation which consists of the formation of a new acetabulum on the wing of the ilium as near the original acetabulum as possible is performed by many surgeons. This procedure is more suitable for patients ten years of age and over Ponseti has shown that when the femoral head cannot be reduced into the primary acetabulum the hip will always be mechanically defective even following the shelf operation Degenerative changes appear after a few years causing severe pain and limitation of motion He advocates the Schanz osteotomy in these cases He also advocates the Schanz osteotomy in young patients, even before puberty, if the femoral head tends to become more and more displaced upward and backward beneath the iliac wing In the latter group if the angle of osteotomy diminishes, a second operation is performed after puberty

After full growth is attained the shelf operation Lorenz bifurcation operation or Schanz osteotomy may be employed

The following procedures utilized in open reduction are mentioned only to be condemned gouging out of the acetabulum alone or paring down the head of the femur Usually these operations are followed by aseptic necrosis marked arthritic changes, pain and stiffness

Traction Prior to Operation.—The amount of resistance encountered in bringing the head of the femur to the level of the acetabulum is variable in different individuals and increases with age. Traction prior to open operation is advantageous in that reduction is facilitated and trauma to the head of the femur thereby diminished Further after operation the tension of the soft tissues will cause less pressure on the articular surfaces of the joint, and consequently less danger of recurrence of the dislocation or subsequent degenerative changes in the head of the femur In older children with materially shortened muscles and a capsule adherent high on the ilium disappointment is likely if one anticipates that the head will be uniformly opposite the acetabulum by traction alone Allison employs a two-stage procedure At the preliminary operation the capsule is stripped from the ilium the iliopsoas muscle is incised and skeletal traction carried out for three to four weeks. Open reduction is then performed in the routine manner

Abbott Colonna Crego and others stress the advisability of preliminary stretching of the structures about the hip by means of adductor tenotomy and skin traction or skeletal traction through the lower end of the femur, or in some cases, a subperiosteal stripping of the gluteal muscles prior to the institution of traction

Open Reduction

As early as 1905 Sherman in this country reported an operation for reduction of congenital dislocation of the hip Before that time Hoffa in Europe had developed a technic of open reduction and had written extensively upon the subject Galloway in 1920 advocated the universal adoption of open reduction preferably when the child is twenty months of age

Open reduction alone is seldom satisfactory after the child reaches the age of four or five years, the operation should then be supplemented by a plastic procedure to reform the acetabular roof The anterior iliofemoral incision (p 146) provides an adequate operative field in practically every case.

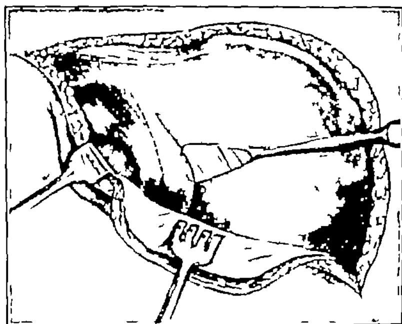


Fig. 1112.—Open reduction of congenital dislocation of hip. Exposure by anterior iliofemoral incision. Capsule stripped from ilium and incised longitudinally as indicated.

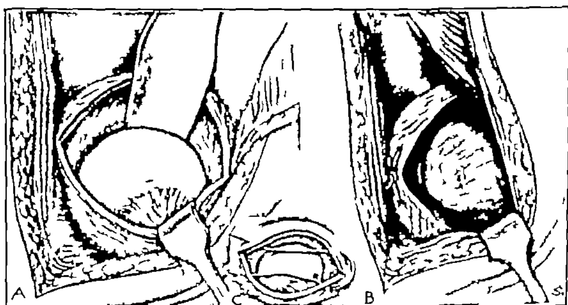


Fig. 1113.—Same as Fig. 1112. *A* After clearing acetabulum, hip reduced with aid of skid. *B* and *C* Method of plicating capsule.

Technic (Galloway)—After proper exposure the head of the femur is located above and posterior to the acetabulum The capsule is incised vertically over the head, and the index finger is inserted through the opening to locate the constricting portion of the capsule and the acetabulum. A blunt pointed hernia knife is passed along the finger the constricting portion in

cised and the acetabulum exposed The fibrocartilage which often fills the acetabulum is removed while the true cartilaginous lining of the acetabulum is preserved intact Reduction is facilitated by the use of a blunt pointed gouge which serves as a lever after the manner of a shoe horn No attempt is made to close the capsule

After Treatment —The hip is immobilized in a cast, in the position of full extension, 140 to 120 degrees abduction and slight or pronounced internal rotation depending upon the degree of torsion of the neck After six weeks, the cast is removed the abduction and internal rotation are diminished, and a second cast is applied which does not include the knee The child is now encouraged to bear weight on the extremity A third and even a fourth plaster cast may be applied at intervals of two months, the abduction being diminished with each successive dressing

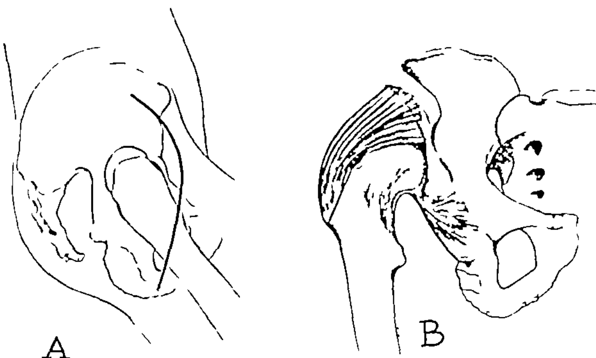


Fig. 1114.—Colonna arthroplastic procedure for congenital dislocation of hip. *A* Skin incision. *B* Trochanter removed. Diagrammatic view of hourglass contracture of capsule (From Colonna, P C. Surg Gynec. Obst. 63: 777 1936)

In our experience such a long period of immobilization has been unnecessary particularly in older children Instead the hip is maintained in 120 degrees' abduction and moderate internal rotation and the knee in extension by means of a double spica cast extending from the nipple line to the toes on the affected side and to the opposite knee. If the reduction is unstable in this position the cast should be applied with the hip in 90 degrees' abduction and external rotation After eight weeks the cast is bivalved and gentle exercises are begun Unsupported weight bearing is permitted after three months.

Technic (Kidner) —With a periosteal elevator the medial layer of the capsule is dissected away from the ilium down to the acetabulum thus permitting elongation of the capsule Upon slight traction the head may then be displaced opposite the acetabulum The capsule is incised and reduction effected as described in the Galloway technic To add stability the capsule is sutured with its edges overlapped

Technic (Hey Groves)—This procedure differs from those described principally in that the longitudinally incised capsule is sutured transversely to eliminate its laxity. A long nail is driven through the trochanter into the rim of the acetabulum just above the socket and incorporated in the cast to insure maintenance of the reduction. The nail is removed after a few days, without disturbing the efficiency of the cast.

In 1932 Colonna devised an arthroplastic procedure for congenital dislocation of the hip in children based upon principles previously described by Hey Groves. Colonna states that the upper age limit for the operation in children with unilateral dislocation should be ten years, and that bilateral dislocation is more often successfully treated by this method in children under eight years of age. The procedure is designed to reduce the dislocation, restore stability of the hip joint, and at the same time preserve a satisfactory range of motion. The operation is performed in two stages.

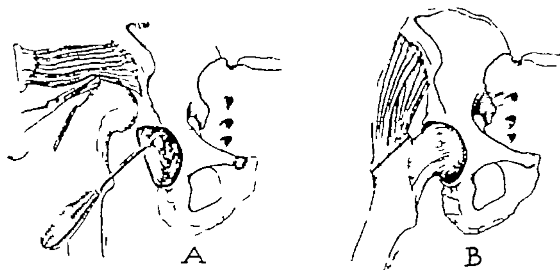


Fig. 1115.—Same as Fig. 1114. *A*, Capsule dissected free from surrounding structures, incised at isthmus, and closed by several sutures over head of femur. Acetabulum enlarged. *B*, Head, with synovium lined capsule, placed in newly formed acetabulum. Greater trochanter reattached. (From Colonna, P. C.: Surg. Gynec. Obst. 63: 777, 1936.)

Technic (Colonna)—(First Stage.) An attempt is made to lengthen the contracted structures and bring the head of the femur to the level of the malformed acetabulum. In younger patients, this is accomplished by thorough stretching and subcutaneous tenotomy followed by skin traction, and in older children by skeletal traction on the lower end of the femur. In more resistant cases, the gluteal muscles may be stripped subperiosteally. To immobilize the pelvis during the period of downward traction on the affected limb, a well padded long plaster spica cast is applied to the opposite side and traction of fifteen to twenty five pounds instituted until the head of the femur is opposite the site of the original acetabulum. This first stage may require two to three weeks or even longer. Colonna advises that the second stage must be delayed until the maximum degree of correction has been obtained and the proper position of the head proved by roentgenograms.

Technic.—(Second Stage.) The hip joint is exposed by a skin incision beginning two inches behind the anterior superior spine and curving forward, downward and backward to a point two inches below the tip of the greater trochanter. The rectus femoris tendon, if contracted, is divided by a Z-plastic tenotomy. The fascia on the lateral aspect of the thigh is incised

transversely and a portion of the greater trochanter, with the gluteal muscles, detached and turned upward. The portion of the capsule covering the head of the femur is separated from surrounding structures by dissection with scissors. The isthmus of the capsule is divided, the head of the bone inspected and the opening in the capsule sutured over the head with several chromic catgut sutures. With a reamer or large curet a spacious acetabulum is formed as near the original site as preliminary traction has allowed. The capsule covered head is then gently reduced into the newly formed acetabulum. The abductor muscles, with the attached cartilage from the greater trochanter, are sutured into place.

After Treatment.—A long plaster spica cast is applied and retained four weeks. The entire cast is then removed, the limb is suspended with 5 to 10 pounds of traction, and a pillow is placed between the legs to maintain abduction of 10 to 20 degrees on the affected side. Active and passive motion are begun as soon as the patient is removed from the cast. The patient is encouraged to sit up, but in order to prevent the development of any flexion contracture at the hip should be turned on his abdomen for a part of the day. Weight bearing is not allowed until a good range of active and passive motion in bed can be demonstrated and any tendency to adduction and flexion has been corrected. This period usually varies from three to six months.

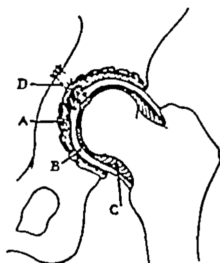


Fig. 1116.—Hey Groves' method of utilizing capsule to reline acetabulum following open reduction. Capsule sutured over head, the stitches being left sufficiently long to form an artificial ligature. *A*, New acetabulum. *B*, Capsule with *C*, synovial lining. *D*, Sutures in capsule passed through hole in acetabulum. (Redrawn from Hey Groves, E. W.: Robert Jones Birthday Volume, p. [illegible]3, London, 19[illegible]3, Oxford University Press.)

The use of braces to protect the hip against weight bearing is not advocated.

The arthroplastic procedure described by Hey Groves in 1927 differs from that of Colonna chiefly in the formation of an artificial ligamentum teres, which lends stability to the reduction until the capsule becomes adherent to the reconstructed acetabulum.

Technic (Hey Groves).—After exposure of the hip joint, the capsule is freed on all sides and its attachment to the rim of the acetabulum incised. A sufficient amount of capsule is retained to make an ample covering for the femoral head; if there is an hourglass constriction, the capsule may be cut across the joint proximal to this point. The opening in the capsule is closed over the head of the femur by means of strong ligatures, the ends of which

are left long The acetabulum is now deepened by gouges and reamers as far as possible below the level of the anterior inferior spine, a space being *created of adequate size to receive the femoral head and its capsular covering* The inner table of the ilium is exposed subperiosteally and the iliacus muscle retracted A hole is then drilled through the floor of the acetabulum and a large aneurysm needle is passed through the hole from within outward the ends of the ligature in the capsule are threaded through the eye in the needle and drawn through the hole in the acetabulum from without inward The femoral head is next placed in the socket and the ligature pulled tight, drawing the capsule into its new position as a lining for the acetabulum The ends of the ligature are brought forward and tied.

By thus releasing the capsule, an envelope is formed for the head of the femur and the natural synovial lining is preserved The capsule adheres to the raw surface of the new socket yet retains its original function of holding the articulating bones together

Correction of Anteversion by Osteotomy

In children from three to seven years of age, the same principles apply as described on p 1600 Since anteversion increases with development and growth correction is more frequently indicated in this age group Manual osteoclasis or osteotomy may be employed the latter being the procedure of choice.

Technic (Hey Groves) —The extremity is immobilized in internal rotation for a period of three to four weeks, by means of a single spica cast. The cast is then removed from the middle of the thigh downward and a subcutaneous *supracondylar osteotomy of the femur performed (p 1370)* The leg is rotated externally to the neutral position and the cast completed from the mid thigh to the toes on the affected side. The corrected position is maintained for eight weeks. Thereafter treatment is carried out as above described.

In children three to four years of age we have often observed a persistent external rotation deformity of the hip joint, even *after months of* physical therapy and muscle re-education If anteversion is pronounced correction may be obtained by a supracondylar or subtrochanteric osteotomy

Shelf or Bone Plastic Operations

In practically every congenital dislocation of the hip the acetabulum is extremely deficient after the patient reaches the age of four or five years. At operation one may determine by passive movements whether the acetabular rim is capable of maintaining the reduction If not stability of the hip may be secured by a plastic procedure on the acetabular rim wherein a bony buttress is created above the head of the femur

In neglected congenital dislocations, shortening varies from one and one-half to four inches, and the acetabulum is small and inadequate. Because of instability pain and fatigue are excessive In addition lumbar lordosis, which is exaggerated by the effort to compensate for the posterior and upward displacement of the femur usually causes low back pain. In this group even if reduction could be effected and maintained the subsequent arthritic changes would be so extensive that disability would be severe. To alleviate the symptoms the head of the femur is *displaced forward to a point directly*

above the acetabulum and a new acetabulum constructed at this point stability being secured also by means of a bony shelf above the head of the femur

The shelf operation for irreducible dislocation of the hip is a palliative procedure for an abnormal mechanical condition In the majority of cases this operation permits a functional range of motion and provides a stable weight bearing surface which is sufficient to reduce pain to a minimum and afford a maximum of endurance

From a study of sixty nine cases of untreated unilateral congenital dislocations of the hip A R Smith showed that material disability from pain is not likely until the patient reaches the age of fifteen In bilateral dislocation, pain is usually present at the age of ten years. He also studied the end results of shelf operations and found that if these procedures are employed before the age of ten years, the new shelf frequently is absorbed and a supplementary osteotomy is necessary In view of these facts, the advisability of the shelf operation for irreducible dislocation of the hip in patients under the age of ten years would seem questionable Others, however, differ with this opinion.

Immediately following shelf operations, unless an extremely deep acetabulum has been constructed the femur tends to dislocate from the acetabulum and displace the fragments which form the shelf. To prevent this complication, traction must be exerted continuously from the time the shelf is turned down over the head until the bones forming the shelf have solidly united with the ilium This is accomplished as a rule by skin traction incorporated beneath the cast

Haas utilizes a pin for fixation following shelf operations. After reduction of the head into the remains of the acetabulum the greater trochanter is exposed and a pin is driven through the trochanter at such an angle that the point engages the acetabulum just above the head After suture of the capsule the shelf operation is carried out. The pin is incorporated in the cast and is not removed until union between the shelf and ilium is sufficiently solid to prevent displacement of the head of the femur

Technic (Frank Dickson).—As a preliminary measure ten to fifteen pounds of weight are applied to the extremity by means of a Kirschner wire through the tibia just below the tubercle, and maintained for a period of three weeks. The patient is then placed on a fracture table and traction is exerted on both extremities.

Through the anterior iliofemoral incision (p 146) the head of the femur is stripped of all soft tissue structures which interfere with complete mobility this usually includes the iliopsoas muscle from the inner surface of the ilium By leverage and traction the head is next brought forward to a position just above the acetabulum A bone flap one and one half to two inches in depth and at least one half inch thick at its base is turned downward over the femoral head adequately covering the anterior and posterior portions, and wedges of bone are removed from the crest to fill the space over the shelf. If necessary tension of the adductor tendons is released by tenotomy

After Treatment.—The hip is immobilized in a cast which includes both hips and extends below the knee on the affected side Strong traction is exerted on the hip as the patient is transferred from the table to the bed in the operating room, and traction is maintained continuously thereafter for six

weeks. Physical therapy and passive motion are begun after four weeks. Unrestricted weight bearing is not permitted until eight weeks following operation.

Dickson observes that unsatisfactory results are traceable to one of three causes (1) failure to mobilize the head sufficiently and displace it forward, (2) attemptes to secure a greater length than is feasible, and (3) over prolonged immobilization following operation.

Technic (Albee) —*After exposure by the anterior iliofemoral incision* and reduction of the dislocation the amount of deficiency of the acetabular rim and the degree of laxity of the capsule are determined With a thin osteotome, the acetabular rim is divided just above the insertion of the capsule, in a *semicircular line conforming to the natural curve of the acetabulum* This segment of bone is pried outward and downward with an osteotome, and secured in position by a triangular or keystone cross section of bone removed from the crest of the ilium or tibia. Usually three keystone grafts are inserted This necessarily increases the laxity of the superior capsule, which is corrected by reefing or plication with a row of mattress sutures of kangaroo tendon.



Fig. 117 —Bilateral congenital dislocation of hips treated by manual reduction.

Gill employs three types of shelf operations, according to the difficulty of securing reduction Type I is indicated if reduction is accomplished without opening the capsule Type II if the capsule must be incised and Type III, when reduction of the head into the original acetabulum is not feasible.

Technic (Gill)—Type I.—If reduction is satisfactory the capsule of the joint is not opened A bone flap elliptical in shape and of a width adequate to cover the portion of the femur which projects beyond the acetabulum, is resected from the outer table of the ilium as follows Beginning at the



Fig. 1118.—Same patient as shown in Fig. 111 three years after closed reduction of right hip and open reduction and shelf operation on left.

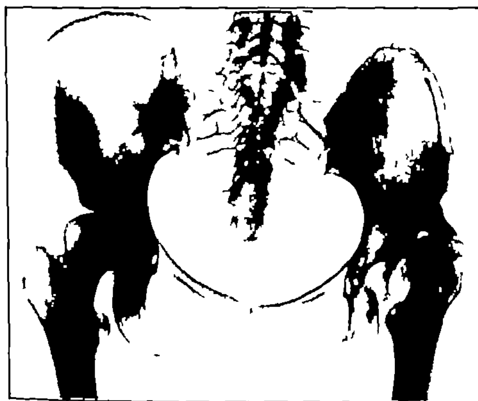


Fig. 1119.—Same patient as shown in Fig. 111 at eighteen years of age, fifteen years after first visit. Right hip practically normal. One inch shortening of left lower extremity compensated for by elevation of heel. Patient walks without limp. Note hypertrophy of shelf as compared with appearance twelve years previously

anterior margin of the pelvis, an osteotome is driven downward almost parallel to the surface of the ilium then, as the upper portion of the roof of the acetabulum is approached, the instrument is directed inward and the entire roof is detached The flap is bent downward anteriorly and forward posteriorly, so that its free edge covers the upper and posterior aspects of the head. Gill states that the flap may be bent through an angle of more than 90 degrees. Finally, several broad, thick wedges of bone are removed from the crest of the ilium and placed into the defect to hold the flap in firm contact with the head

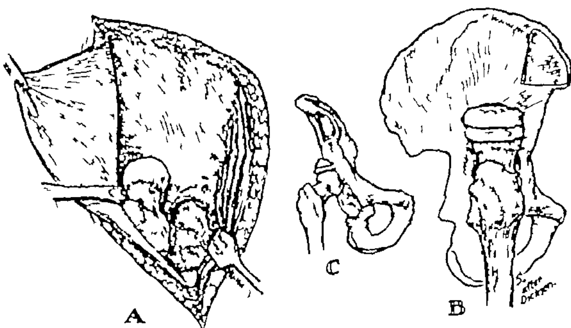


Fig. 1120 —Dickson shelf operation. *A* Exposure of dislocated hip and mobilization of head of femur permitting forward transference of head onto ridge between anterior and posterior planes of pelvis. *B* and *C* Flap of bone turned down from crest of ilium over head of femur and held in place by wedge graft. (Redrawn from Dickson, F D.: J Bone & Joint Surg. 17 42 1935)

Technic—Type II.—The capsule is incised close to the ilium, beginning at the anterior inferior spine and proceeding posteriorly one and one-half to two inches. In the presence of an hourglass constriction, the capsule is also incised upward to the head of the femur at a right angle to the first opening This permits delivery of the head into the wound. With scissors or a curved gouge, the fibrous tissue which fills the acetabular cavity is removed the head is then reduced As a rule, the acetabulum is not of proper size and shape for a stable reduction. A boneflap is next turned down from the site of the ilium and the roof of the acetabulum as described above. The capsule is brought up over the bone flap but cannot, as a rule, be sutured. Reduction is generally stable if the hip is maintained in slight abduction and internal rotation.

Technic—Type III.—The head of the femur is exposed as in Type II. In order to displace the head forward the capsule must be incised throughout its length, beginning at the middle of the horizontal incision and extending backward and upward to the head of the femur The degree to which the head of the femur can be brought toward the acetabulum is determined by moderate traction. With a curved gouge the acetabulum is enlarged upward and backward until of adequate size to receive the head. Reduction is then effected. The joint usually is stable if the extremity is maintained in slight ab-

duction A bone flap one inch or more in width is turned down before, above and behind the head

Technic (Compere-Phemister) —Traction is applied prior to operation often, reduction may then be effected without incision of the capsule

Into slots drilled above the acetabulum are driven three grafts from the tibia each one by two inches Over these two similar grafts are laid

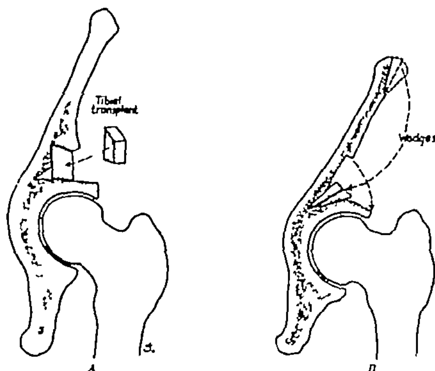


Fig 11 1 —*A* Albee shelf operation (1915) *B* Shelf operation of Gill.

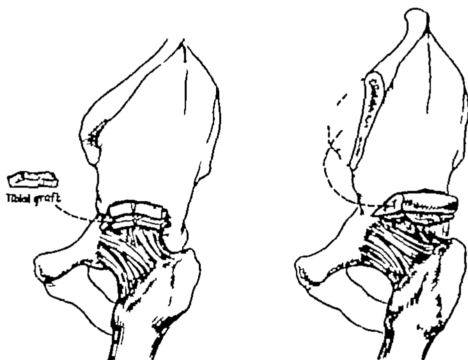


Fig. 1122. Fig. 1123.

Fig. 1122.—Shelf operation of Compere and Phemister (Redrawn from Compere, E. L. and Phemister D. B. J Bone & Joint Surg 17: 60 1935)

Fig 1123.—Shelf operation of Ghormley (Redrawn from Ghormley R. K. J Bone & Joint. Surg. 13: 784 1931.)

Technic (Ghormley).—The head of the femur is drawn down as far as possible on the traction table and chips of bone are turned downward over the head the capsule remaining intact These chips are cut with a slightly curved chisel in such a manner as to have their heaviest portions or bases as close to the head or the new acetabular margin as possible. A sufficient number are laid down to form a fairly straight groove above the acetabulum. The anterior superior spine and anterior portion of the iliac crest are next freed entirely of periosteum and muscular attachments, and this portion of the ilium is removed with a chisel The cut surface is beveled sharply and placed in the groove above the acetabulum and the graft is driven into the cancellous bone of the ilium

Technic (Lowman).—The head of the femur is brought forward over the acetabulum and a new socket one and one-half inches in diameter and one half to three-fourths inch in depth, is formed Two rectangular flaps, each one inch long their bases one fourth inch apart just above the new socket, are outlined one points upward and forward the other upward and backward.

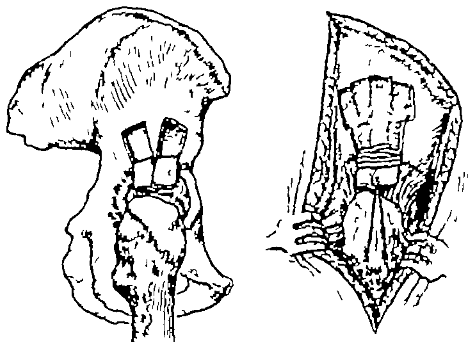


Fig. 1121.—Shelf operation of Lowman. (Redrawn from Lowman, C. L. J. Bone & Joint Surg. 13: 511 1931.)

A small hole is drilled in the upper corner of each one-fourth to three-eighths inch from the adjacent margins. The head is reduced into the new socket and the flaps are turned downward over the head and sutured together through the drill holes. The ends of the suture, which should be four to six inches long are passed into the tissue over the trochanter thus, loss of abduction serves to pull the flaps closer to the head Bone chips are packed above the flap

Lowman s operation is advantageous in that a concave rather than a flat surface is provided moreover the flaps are easily maintained in position.

Bucket-Handle Acetabuloplasty.—Nachlas has devised an operation for repair of defects in the acetabular roof which is a departure from ordinary shelf operations. This procedure is designed to reproduce the hemispherical shape of the normal acetabulum by a simple technic. Prior to operation,

shortening and contracture must be overcome sufficiently to permit reduction of the head of the femur into the original acetabulum without tension This is accomplished by traction or by a preliminary stripping operation (p 1088) Necessarily, in congenital dislocation of the hip the procedure is limited to the younger age group (Nachlas' patients were aged four five, five and six

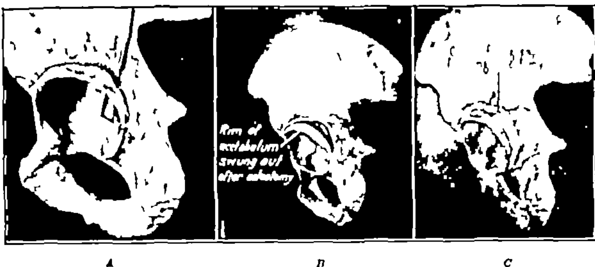


Fig 11 —Bucket handle acetabuloplasty for repair of defects in acetabular roof (Nachlas) *A* Line of osteotomy through acetabular roof showing direction of osteotome. *B* Upper rim of acetabulum swung outward as a bucket handle, leaving anterior and posterior ends attached. *C* Defect filled with callus, reforming acetabular roof. (Courtesy of Dr I. H. Nachlas.)

A B

Fig. 1124 —*A* Congenital dislocation of hip in child aged five years. *B* After bucket-handle acetabuloplasty (Courtesy of Dr I. H Nachlas.)

years) *In older children, the acetabulum is extremely inadequate* and it is difficult or impossible to bring the head of the femur into this socket without tension (Nachlas patients in whom this technic was employed for paralytic dislocation were nine fourteen and twenty two years of age.)

Technic (Nachlas) —The hip joint is exposed by an anterior iliofemoral incision (p 146) *To facilitate replacement of the head of the femur into the* acetabulum the capsule is incised longitudinally on its superior aspect from the ilium to the greater trochanter After reduction of the dislocation a semicircular incision is made above the attachment of the capsule, and the outer aspect of the ilium immediately above the deficient acetabulum is exposed An osteotome is then driven directly into the joint from the outer aspect of the ilium The rim of the acetabulum is thus freed superiorly but is left attached at each end i e., posteriorly and anteriorly This segment is then reflected laterally swinging on its attached ends like a bucket handle With moderate care the attached ends will not be broken. The final position of the rim is commensurate with the amount of lateral displacement necessary to cover the head adequately A block of bone from the crest of the ilium is forced into the line of cleavage to maintain this position

After Treatment.—A double spica cast is applied which holds the hip in abduction. Immobilization is continued for two months and is followed by traction for an additional month Weight bearing may then be resumed gradually

Nachlas observes that the operation is fundamentally a simple incomplete osteotomy in a location where the blood supply is particularly good. Since the essentials for good bone repair are present, one may anticipate the formation of callus to fill the gap, the spherical head of the femur acting as a mould to shape the callus.

Osteotomy for Irreducible Dislocation of the Hip

Lorenz Bifurcation Osteotomy—This procedure is less popular in the United States than abroad In the Rizzoli Institute osteotomy is the method of choice for irreducible dislocations of the hip in patients above the age of fifteen years. The purpose of the operation is the establishment of a bony support for the femur The chief indication is pain at the site of the false acetabulum on the wing of the ilium. As suggested by Massart, the osteotomy may be combined with the shelf operation or if pain should be excessive following a shelf operation, may be carried out as a supplementary procedure.

The operation described by Lorenz consisted of an oblique osteotomy in an upward and medial direction as viewed from the front. The shaft was then reduced into the capsule-covered acetabulum, while the raw surface of the proximal fragment was placed in contact with the shaft.

Haas, in 1924 described a modification of the Lorenz bifurcation osteotomy Instead of an oblique osteotomy in one plane the femur is divided in an oblique frontal plane from below posteriorly to above anteriorly to provide a relatively large area of contact of the raw osseous surfaces and prevent flexion of the upper fragment with possible injury to the femoral vessels.

Technic (Haas) —The upper third of the femur is exposed through a lateral incision (p 179) The proximal end of the osteotomy should be opposite the acetabulum the lesser trochanter being included in the proximal fragment. To determine the exact line of division, a drill is inserted from below posteriorly to above anteriorly extending upward and inward toward the

acetabulum A roentgenogram is made to insure the correct position The shaft of the bone is then divided in this plane with an osteotome. The distal fragment is next abducted so that its proximal end rolls inward, upward, and anteriorly into the acetabulum and a portion of the raw areas of the two fragments remains intact A layer of capsule is thus interposed between the sharp end of the distal fragment and the articular surface of the acetabulum

After Treatment.—A double spica cast is applied from the nipple line to the knee on the normal side and to the toes on the affected side immobilizing the thigh in 140 degrees' abduction and 170 degrees' flexion The cast is removed after eight weeks and physical therapy is begun At three months, full weight bearing is allowed with the aid of a Thomas caliper walking brace reinforced by an abduction piece (p 45)

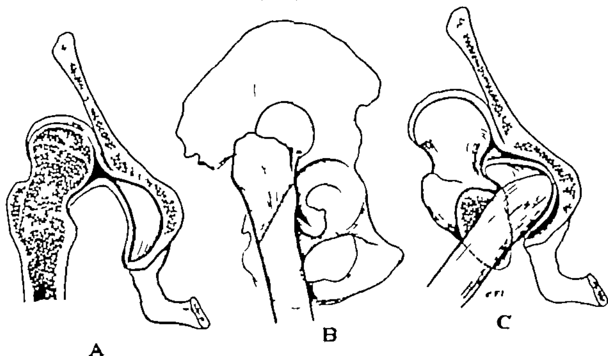


Fig. 1127—Lorenz bifurcation operation. Femur divided in oblique frontal plane from lateral side.

Schanz Osteotomy—In congenital dislocation of the hip, when weight bearing is instituted the pelvis on the opposite side must drop sufficiently to allow impingement of the pelvis on the affected femur By eliminating this feature, an improvement in the lurching gait may be expected. This is accomplished in principle by an osteotomy which angulates the upper fragment medially against the pelvis while the lower fragment is parallel to the normal weight bearing line of the extremity

Gaenslen lists the relative advantages and disadvantages of this procedure in comparison with the Lorenz bifurcation as follows. Advantages (1) better range of motion, (2) less shortening (3) improved stability because of tension on the gluteal muscles through depression of the trochanter, the outward displacement of the trochanter being a distinct mechanical aid to the glutei (4) frictional support by contact of the upper fragment with the pelvis and (5) improvement in lordosis by bowing of the fragments forward as well as toward the midline. Possible disadvantages are (1) genu valgum (2) nonunion (3) splintering of bones, endangering vessels and nerves and (4) excessive angulation.

Some of these difficulties are now overcome by the use of internal fixation chiefly the Blount blade plate thus efficiently maintaining the fragments in the proper position with a minimum of external support

Preoperative preparations are carried out as follows With the affected hip in the maximum degree of adduction a roentgenogram is made to ascertain the amount of angulation necessary to appose the femur to the *pelvis at the* osteotomy site and place the distal portion of the extremity in the longitudinal axis of the body The most suitable site for the osteotomy is the level of the *tuberosity of the ischium A variety of lengths of the gooseneck blade plates* should be available, the lower angle of the plate corresponding to the calculated angle of the osteotomy An error in the angle of the blade may be adjusted with benders

Technic (Blount)—The trochanter and lateral aspect of the femur are exposed by a lateral incision (*p* 179) A guide pin is inserted into the femur at the level of the proposed osteotomy site and another is placed through the trochanter into the neck and head of the femur The proper level for the *osteotomy having been verified by roentgenograms the lateral third of the* shaft of the femur is divided A Blount plate of proper angles and dimensions is next inserted into the trochanter neck and head along the predetermined line A screw fixes the blade to *the* proximal end of the bone. The distal end of the blade should form an angle with the shaft, equal to the predetermined angle of the osteotomy The osteotomy is then completed the fragments angulated into proper position, and the blade is fixed to the shaft by an appropriate number of screws

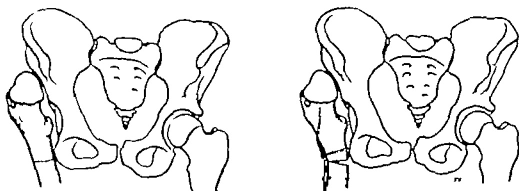


Fig. 1128—Schanz osteotomy for irreducible dislocation of hip. Fragments controlled by Blount blade plate.

After Treatment.—As a rule fixation will be sufficiently firm that a cast will not be necessary At most, the extremity may be supported in a balanced traction splint. Usually, patients may be up on crutches eight to ten weeks postoperatively Unsupported weight bearing is not allowed until union is unquestionably demonstrated by roentgenograms.

Osteotomy and Open Reduction.—Swett, *in 1928, reported an operation* for old or neglected congenital dislocations of the hip wherein reduction is impossible by the usual methods. The operation, which consists of an osteotomy below the trochanter of the femur *is designed to adjust the disproportion* between the length of the bone and the soft parts. Since the acetabulum and head of the femur must be of fairly normal shape and proportions, the usefulness of the method is necessarily limited Further because of the

possibility of complications, such as malunion or nonunion, from a single stage open reduction and osteotomy below the lesser trochanter, the advisability of the operation is questionable

Technic (Swett)—After exposure by the anterior iliofemoral incision, the outer and upper portions of the capsule are opened widely To secure the maximum mobility of the head the muscle attachments about the trochanters are dissected free The acetabulum is next cleared of all redundant capsular and fibrous tissues. A transverse osteotomy is then carried out below the lesser trochanter and the fragments are allowed to overlap The femoral head is reduced into the acetabulum and stabilized by plication of the capsule.

After Treatment.—By means of a plaster cast, the hip is immobilized in full extension and moderate abduction for twelve weeks. Swett believes a better position of the fragments at the osteotomy site could probably be secured by redressment at three weeks, or possibly by moderately strong traction either immediately after operation or at the end of three weeks.

According to its originator the most disappointing aftermath of the procedure is a disturbance of growth in the upper end of the femur the head becomes smaller and the neck angled in relation to the shaft to a greater or less degree than normal.

The above operation is similar to the one employed by Hey Groves in 1926 for correction of an old bilateral dislocation of the hip Instead of performing an osteotomy Hey Groves removed a two-inch section of bone from the femur just below the lesser trochanter Alignment and position were maintained by an intramedullary peg which was fixed in place by a screw A *Lorenz osteotomy was to be performed on the opposite hip*

CONGENITAL COXA VARA

Congenital coxa vara is a deformity of the hip frequently bilateral, characterized by a progressive diminution of the angle between the neck and shaft. As a rule conservative measures are of little or no value in arresting the progress of the deformity Surgical treatment is carried out principally to correct adduction and arrest the growth of the upper femoral epiphysis. The prospect of obtaining a hip which approaches normal, however is poor

Zadek suggests drilling of multiple holes in the neck of the femur to increase the blood supply and theoretically to stimulate ossification. Either at the same time or later a subtrochanteric wedge osteotomy is performed to correct the angle of the neck

Sorrell has performed a cuneiform resection at the junction of the trochanter and the neck in one case of congenital coxa vara, with an excellent result. The apparent shortening was 6 or 7 cm., although the actual shortening was only 3 cm The roentgenogram showed that the angle between the neck and shaft of the femur was only 80 degrees and the epiphyseal line was almost perpendicular Prior to operation the shape and dimensions of the wedge were determined by a study of the roentgenogram the angle of the wedge being approximately half the difference between the angle of the normal hip and the coxa vara angle In the case in question, the angle of the wedge was 20 degrees, or half the difference between 120 degrees and 80 degrees.

Technic (Sorrell)—The trochanter neck and upper portion of the shaft of the femur are exposed through a longitudinal incision parallel to the an

terior border of the greater trochanter A wedge of bone with its base upward and outward is resected from the neck and trochanter The extremity is then abducted and the wedge reinserted in a reverse position i e with its base downward and inward

After Treatment.—Immobilization is continued for four months by means of a plaster cast

In Sorrell s case, union took place uneventfully Six months after operation the patient walked without a limp the Trendelenburg sign was negative, and the angle of the neck and shaft was normal.

Peabody feels that the proper treatment of severe congenital coxa vara involves the use of an osteotomy to prevent untoward displacement in the correction of a high degree of deformity In addition the epiphyseal area should be stabilized early as the active chondral dystrophy and instability of prenatal origin are limited to the infantile years. After this period instability is residual only in the presence of shearing strains If the latter element can be eliminated or be replaced by axial stress, the epiphyseal plate may be left to mature naturally, and length will be preserved

Technic (Peabody)—From a paper pattern of the femur, a pattern of the small wedge resection and a protractor pattern of the angles of the Riedel pin are made duplicated in tin or aluminum and sterilized A curved incision is made from over the tip of the greater trochanter to the level of the junction of the middle and upper thirds of the shaft, the belly of the curve being anterior Following the intermuscular planes the vastus lateralis muscle is stripped from both the lateral and anterior aspect of the intertrochanteric region exposing this region from the greater to the lesser trochanter By means of a curved elevator, the lesser trochanter is exposed at the base of the neck.

A diagonal bone cut is made laterally and proximally from the mesial cortex at an angle of 45 degrees to the shaft ending at or a little medial to the midpoint of the intertrochanteric line Using the previously prepared metal protractor as guides the two Riedel pins are inserted the upper one deeply through the neck and head the second below in the shaft. With a motor saw or osteotome the wedge is removed laterally the apex of the wedge is at about the midpoint of the bone almost meeting the upper end of the first osteotomy cut at this point. This acts as a central pivot point on which the femoral shaft moves as the thigh is abducted the wedge resection gap is closed with an opening up of the mesial saw cut as this realignment is secured The two Riedel pins are secured by a two-plane clamp Before the clamp is applied the proximal pin is backed out until it engages only in the head and neck The removed wedge is then impacted into the open mesial cut. Following closure of the wound a plaster spica cast is applied and maintained until healing is complete.

Duncan feels that subtrochanteric osteotomy is the best procedure in the treatment of this condition. Despite the surgery he considers this a conservative form of treatment. He reports a series of thirty-one patients, eighteen of whom were operated upon. *Twenty subtrochanteric osteotomies* were performed with good results. The deformity was well corrected in all patients except two in the latter sufficient abduction was not obtained at the time of operation A repair of the deformity at the epiphyseal line was attempted in three cases though the results were unsatisfactory

ANOMALIES OF THE VERTEBRAE

Only the anomalies of the vertebrae which frequently necessitate surgical treatment will be discussed, namely, hemivertebra, sacralized transverse processes and spondylolisthesis With the exception of hemivertebra these anomalies are most often observed at the fifth lumbar vertebra

Hemivertebra

The body of the vertebra arises from two growth centers Lack of formation or cessation of growth of either of these centers results in an absence of one-half the vertebra or a wedge shaped vertebra, as seen in the anterior posterior view in the roentgenogram

Until the age of adolescence partial absence of a vertebra, or hemivertebra, is treated by apparatus to prevent curvature of the spine Deformity is especially likely to develop as the vertebra above gravitates downward on the side of the missing portion If the spine is unstable, as indicated by increasing curvature or any other deformity during adolescence, a fusion operation should be carried out The deformity frequently becomes fixed, however eliminating the necessity for operation

In two cases Compere has performed a radical operation for the cure of scoliosis induced by hemivertebrae, practically all of each hemivertebra being removed The following technic was employed for excision of an eleventh dorsal hemivertebra and an accessory hemivertebra between the twelfth dorsal and first lumbar vertebrae both on the left side. The principles of this technic are applicable to the removal of hemivertebrae in other locations. An operation so extensive as excision of a hemivertebra should be undertaken only by a master surgeon, and then only in exceptional cases.

Technic (Compere)—A curved incision is made extending from the eighth dorsal to the third lumbar vertebrae The left sides of the spinous processes and the corresponding laminae are exposed by means of a periosteal elevator The erector spinae muscles are then reflected laterally bringing into view the transverse processes of the eleventh and twelfth dorsal and the first and second lumbar vertebrae These are fractured at their bases.

An incision paralleling the eleventh rib on the affected side is now made connecting with the longitudinal incision and extending laterally for a distance of 10 cm With a small rib stripper the eleventh and twelfth ribs are denuded of soft tissue attachments and the twelfth rib as well as a segment of the eleventh rib 6 cm in length is excised

The column of spinal muscles is now retracted medially and the laminae and pedicles of the vertebrae from the eleventh dorsal to the second lumbar exposed. The parietal pleura is dissected from the bodies of the eleventh and twelfth dorsal and first lumbar vertebrae exposing their lateral and anterior surfaces. Care must be exercised to avoid unnecessary trauma to the nerve roots.

With a small chisel and a dissector the eleventh dorsal hemivertebra on the affected side is removed in several fragments. The bone is excised from the accessory hemivertebra leaving a cartilage-lined defect. The corresponding laminae are only partially excised

The spinous processes and laminae on the affected side are again exposed and roughened with a chisel and curls of bone are turned laterally across the articular facets. The previously removed ribs are split longitudinally and

placed on the laminae as grafts, extending from the eighth dorsal to the third lumbar vertebrae

After Treatment.—Following healing of the wounds, a Hibbs, Risser and Ferguson corrective cast is applied including the leg of the affected side, and thereafter gradual correction of the deformity is continued for a period of three weeks. The gap in the cast is then filled in with plaster and immobilization is maintained until fusion is solid

In the second case, the technic for removal of a hemivertebra at the level of the first lumbar was practically identical, in addition, however the corresponding pedicle articular facet, and lamina were resected

Von Lackum and Smith report ten patients with scoliosis operated upon for removal of vertebral bodies, five with curvatures caused by hemivertebrae, and five with ordinary scoliosis They feel that no patient should be operated upon under six years of age and that the operation should be employed only in cases of lumbar hemivertebrae or lumbar scoliosis. Their only successful cases were those with lumbar involvement

Originally they approached the vertebrae through a dorsal midline incision over the spinous processes this provided a poor exposure of the vertebral body with its pedicle The lamina and pedicle were first removed and then the body The latter had to be removed piecemeal and severe hemorrhage ensued They no longer employ this approach The operation is now performed in two stages the first stage consists of removal of the vertebral body through a lateral lumbar incision with a retroperitoneal approach at the second stage the posterior arches are removed subperiosteally through a dorsal midline incision This technic is then supplemented by an arthrodesis.

Spondylolisthesis

This anomaly is characterized by a defect in the neural arch with a consequent forward displacement of the body of the fifth lumbar vertebra and the superincumbent spine upon the sacrum Less commonly a similar anomaly of the fourth lumbar vertebra is observed The lesion is caused by a lack of fusion of the ossification centers which form the posterior and anterior halves of the neural arch normally fusion occurs at a point between the inferior and superior articular facets. Ordinarily the inferior articular facet of the fifth lumbar vertebra prevents forward luxation of this vertebra on the sacrum. In spondylolisthesis, the inferior articular facet is attached only to the posterior segment of the neural arch of the vertebra and is thus unable to perform its intended function efficiently

Defects of the neural arch frequently present no symptoms and are discovered only by accident in roentgenograms made for other purposes. Or trauma of either an acute or chronic nature superimposed upon a previously painless defect, or any destructive lesion of the neural arch may eventuate in spondylolisthesis In all cases of spondylolisthesis, the possibility of a coexisting protrusion of an intervertebral disc should be considered Meyerding in reviewing the records of 745 patients, found that 80 patients, or 10 7 per cent had sciatic pain and a much larger number had vague referred pain and paraesthesia of the buttocks, hips, and thighs. A diagnosis of protrusion of an intervertebral disc was made in 15 of the 25 cases of spondylolisthesis with sciatica and was confirmed by operation in 6 of the 15

The treatment of spondylolisthesis with associated protruded intervertebral disc is surgical removal of the protruded disc and fusion of the spine

Fusion of the lumbosacral joint by a modified Albee technic utilizing iliac grafts has proved satisfactory The technic of arthrodesing procedures is described in Chapter XV

The posterior bone graft for spinal fusion is obviously less efficient mechanically than an anterior graft The technical difficulties of fusing the bodies of the fourth and fifth lumbar vertebrae from the front, however, and the magnitude of the procedure have prevented use of the anterior graft.

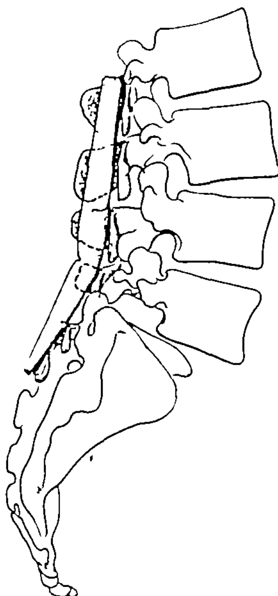


Fig. 1135—Fusion of lumbosacral area for spondylolisthesis by Albee method.

Further as Kellogg Speed states even though the laminae and spinous processes of the sacrum and lower lumbar vertebrae are solidly fused, the body of the fifth lumbar vertebra may advance forward during the course of time Of even greater import 20 per cent of these patients present spina bifida occulta which interferes with proper placement of the graft and fusion of the lumbosacral area

Jenkins Burns Mercer Kellogg Speed and others have reported cases successfully treated by the anterior fusion. Although we have had no experience with any of these procedures that described by Kellogg Speed

Fig. 1130.—Spondylolisthesis before and eighteen months after spinal fusion by Albee technic.

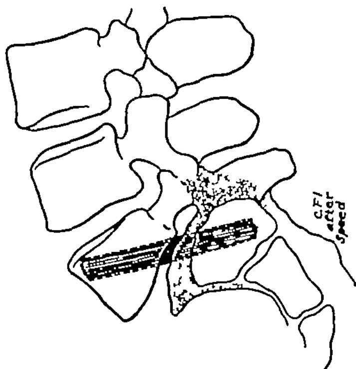


Fig. 1131.—Anterior fusion for spondylolisthesis (Kellogg Speed). Drill passed through body of fifth lumbar vertebra into sacrum. Bony transplant of proper dimensions, from tibia, inserted into hole. (Redrawn from Speed, Kellogg: Arch. Surg. 37: 175, 1938.)

wherein a graft is inserted through the body of the fifth lumbar vertebra into the sacrum would seem the most efficient. Prior to operation an attempt may be made to reduce partially the displacement of the fifth lumbar vertebra by traction though this is usually unsuccessful

Technic (Kellogg Speed).—An incision is made in the midline from the umbilicus to the pubis, fully exposing the sacral promontory The lower end of the table is raised and the intestines are packed away By palpation the relations of the fifth lumbar vertebra and the sacrum are determined and the roentgenographic findings confirmed The bifurcation of the aorta, if low, is retracted with the left common iliac vein The peritoneum is incised from the fourth interspace to the sacrum just to the right of the midline, the mid sacral nerve and artery and the ganglia of sympathetic nerves being avoided.

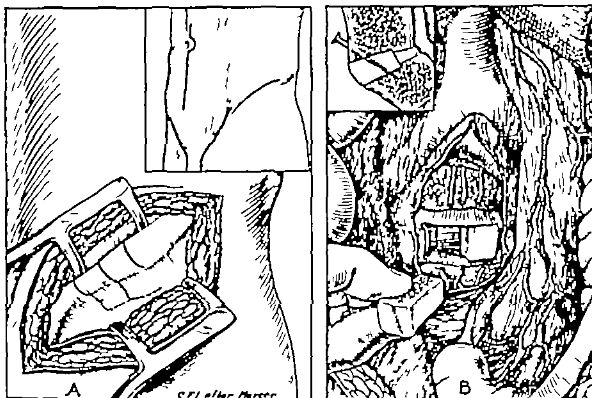


Fig. 1132.—Anterior fusion of lumbosacral joint (Mercer) *A* Preparation of bone grafts from iliac crest. Insert shows skin incisions for exposure of anterior surface of lumbosacral joint and removal of grafts. *B* Exposure of body of fifth lumbar vertebra below bifurcation of aorta. Bone grafts placed in excavation between fifth lumbar vertebra and sacrum. Insert shows method of transfixing vertebra and grafts by metal screw (Redrawn from Mercer Walter Orthopedic Surgery p. 579 Baltimore 1936 Wm. Wood and Company)

A large drill is then inserted through the body of the fifth lumbar vertebra obliquely into the sacrum with the patient in the supine position this is practically in a vertical plane. The proper angle and depth of the drill hole should be previously determined. *The passage of the drill through the lower posterior body of the fifth lumbar vertebra into the intervertebral space and thence into the sacrum is discernible by the sensation produced. A bony transplant of the proper dimensions is then taken from the tibia and inserted into the hole*

After Treatment.—The patient is placed on a moderately firm bed which permits nursing care without flexion of the spine. After eight weeks, a spine brace is fitted and the patient is allowed to be up

Mercer has performed an osteotomy through the lumbosacral joint and filled the defect by two bone grafts removed from the ilium. During the operation the patient lies in the posterior half of a plaster cast or shell.

Technic (Mercer).—The lumbosacral area is exposed as described above *and the soft tissues are dissected away from the space between the sacrum* and the fifth lumbar vertebra. After ligation of all bleeding vessels, an osteotome is driven in an anterior posterior direction into the lower margin of the fifth lumbar vertebra one-eighth inch from its lower edge, and into the sacrum one-eighth inch from its upper edge. Removal of this bone forms a rectangular hole. The intervertebral disk is then resected. The crest of the ilium is next exposed through a second incision and two grafts are excised. These are impacted tightly into the space between the sacrum and fifth lumbar vertebra and fixed by means of a screw.

After Treatment.—The patient remains in a plaster shell for three months. Walking is resumed thereafter, the back being supported by a brace.

Anterior fusion of the lumbosacral joint would seem to carry a greater operative risk than posterior fusion. A sufficiently large series of cases has not been reported to warrant the use of the procedure as a routine measure.

CERVICAL RIBS AND SCALENUS ANTICUS SYNDROME

Symptoms may be of a sensory, motor, or vascular character and of *widely varying degree. They may be constant or may appear only on move*ments which produce tension on the brachial plexus and subclavian artery.

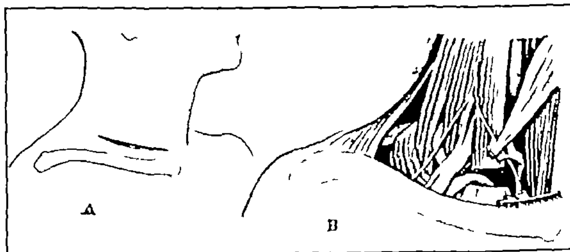


Fig. 1132.—Operation for removal of cervical rib and resection of scalenus anticus muscle. *A*, Line of skin incision. *B*, Diagrammatic drawing showing relation of scalenus anticus muscle to phrenic nerve and subclavian vein. Subclavian artery and brachial plexus directly posterior to muscle. Dotted lines represent distal end of cervical rib.

If roentgenograms reveal the presence of cervical ribs, and symptoms are sufficiently severe, surgical intervention is indicated to relieve pressure on the brachial plexus or subclavian artery by the scalenus anticus muscle, the tendinous attachment of the anomalous rib or the rib itself. If cervical ribs are not present, with pertinent objective findings, the scalenus anticus syndrome is suggested. The common conception of this condition as an isolated clinical entity, probably of idiopathic origin, is questionable. In fact, we are rather doubtful that it ever occurs. In the majority of cases, lesions of the

cervical discs (p 871) or other clinical entities account for symptoms which heretofore were attributed to the scalenous anticus syndrome We are no longer able to formulate the indications for resection of the scalenus anticus muscle alone

Resection of Scalenus Anticus Muscle and Cervical Ribs

Technic.—The incision is begun just lateral to and one inch above the sternoclavicular joint and carried upward and backward a distance of three and one half inches. The platysma and clavicular head of the sternocleido mastoid muscle are incised, and the omohyoid and scalenus anticus muscles exposed The phrenic nerve which runs obliquely across the scalenus anticus muscle, should be dissected free and retracted medially The borders of the scalenus anticus muscle are defined with extreme care to prevent injury to the subclavian vein which is anterior to and usually well below the con templated site of division of this muscle The subclavian artery and brachial plexus are directly posterior After division of the scalenus anticus muscle, therefore pressure on the subclavian artery may be relieved If not the brachial plexus and subclavian artery are retracted forward to determine whether the cervical rib or its tendinous attachment is causing pressure If pressure is obvious, the skin incision is extended posteriorly and the tendinous attachment and anterior portion of the rib are removed with a rongeur or the entire rib is resected

Meticulous caution is important in this procedure as inestimable damage and even death may follow a careless or haphazard technic

TORTICOLLIS
(CONGENITAL WRYNECK)

Many theories have been advanced to explain the development of this condition It is generally held that trauma is the primary cause of the de formity though the method of production is debatable The most plausible explanation seems to be that of Chandler and Altenberg who believe that a number of forces acting separately or together causes an almost complete derangement of the anatomy of the sternocleidomastoid muscle These forces are intrauterine consisting of malposition with a degree of ischemia resulting therefrom and trauma during the delivery Delivery is usually difficult, and frequently is a breech This condition is not related to the torticollis which appears later than infancy and may be due to spontaneous subluxation of the cervical spine platybasia visual disturbances or congenital anomalies of the cervical spine

The primary pathologic feature is entirely limited to the sternocleido-mastoid muscle the subsequent changes in the head face and cervical spine are secondary

At birth or ten to fourteen days later a hard immobile fusiform swelling is noted in the sternocleidomastoid muscle The swelling usually increases in size for two to four weeks, then begins to regress, and may disappear between the fifth and eighth months. The muscle becomes shortened contracted and fibrous and the secondary head and facial deformity becomes more severe

On microscopic section of the swelling or tumor ' the muscle cells are entirely replaced by fibrous tissue No hemorrhage nor hemosiderin is present.

The indication for operation in the older children with fixed deformities is perfectly obvious The most favorable time for operation on infants, however may be difficult to decide many infants with tumors ' at two weeks of age will have no deformity later while others will have a rapidly increasing torticollis deformity

Chandler and Altenberg with whom we agree reserve surgery for those infants who present the more pronounced changes in the muscle and head. The most important factors to be considered are the size of the tumor, the progressive shortening of the muscle and the increasing severity of the associated deformity of the head face and cervical spine

Operation should usually be performed before the infant reaches the age *of three months. The youngest patient operated upon by Chandler and Altenberg* was three weeks of age

Technic (Chandler and Altenberg).—A transverse incision is made through the *skin just above the clavicle exposing the platysma muscle* The latter is split by blunt dissection bringing the tumor into view The tumor is then isolated from the adjacent structures by the same means. The two portions of the sternocleidomastoid muscle are isolated and the muscle is freed from the clavicle by multiple tranverse cuts The tumor is then freed and elevated from the deeper structures and from the wound. The spinal accessory nerve is identified and isolated by cutting through the tumor The tumor is then removed by cutting transversely through the muscle at the junction of the upper and middle third.

After Treatment.—A pressure bandage is applied and the head is held in *the overcorrected position by a starch bandage After two weeks, the bandage* is removed and active and passive stretching are instituted

The severe deformities of neglected torticollis could and should be prevented by early operation Unfortunately many patients are not brought to the attention of the surgeon until the deformities have become fixed as age advances, atrophic changes in the face on the contracted side and asymmetry of the skull increase

A number of operations have been devised for severance of the sternocleidomastoid muscle at the clavicle Operative measures to free this muscle at its attachment into the mastoid process have also been employed Subcutaneous tenotomy of the clavicular attachment has been carried out with success, but this should be abandoned as the procedure is inaccurate and there is some danger of severing the external jugular vein and phrenic nerve. The following measure is preferable

Technic.—An incision two inches in length is made just below and parallel to the sternal extremity of the clavicle down to the heavy rounded tendon of the sternal attachment. The tendon sheath is incised longitudinally and a hemostat or heavy blunt instrument is passed posterior to the tendon separating all its posterior attachments. By traction the tendon is then drawn outside the wound clamped above and below the forceps, and one inch of its *lower extremity is resected. The clavicular attachment of the muscle, fascia,* and platysma is also severed if contracted The chin and head are then twisted in the direction opposite the contracture to an overcorrected position, thus stretching the severed tendon. The wound is closed routinely using a subcuticular stitch if desired and a simple collodion dressing or plain gauze with adhesive plaster is applied

If this procedure does not provide adequate correction the proximal attachment of the muscle is *released through a small transverse incision be*

low the mastoid process. Care should be exercised to avoid damage to the spinal accessory nerve (In one of our cases a facial paralysis existed for six weeks postoperatively, apparently due to trauma from the retractors)

After Treatment.—The patient is placed in bed and head traction is maintained for two weeks the head being held in a straight line After one week

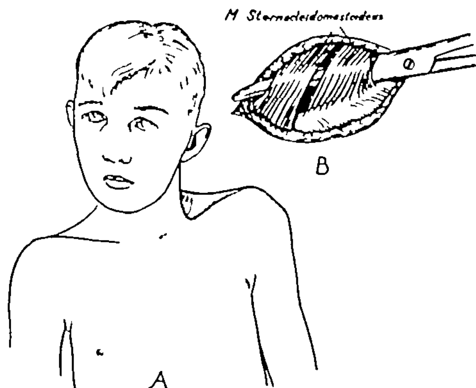


Fig. 1134—Operation for torticollis. *A* Line of skin incision. *B* Clavicular and sternal attachments of sternocleidomastoid muscle withdrawn from wound and divided.



Fig. 1135—Before and after correction of torticollis

physical therapy and manual stretching with overcorrective exercises are begun. The patient is allowed to return home at the end of two weeks. Thereafter manual movements should be continued three times a day for three to six months. For a similar period the patient should sleep with traction on the head In this manner, the use of plaster casts and braces may generally be avoided Physical therapy and manual movements under the direction of a well trained physical therapist are advantageous but are not essential to an excellent result.

Jahss described a peculiar type of torticollis from shortening of the clavicular head of the sternocleidomastoid muscle. This portion of the muscle, which runs from the mastoid almost to the middle of the clavicle is abnormally prominent and does not blend with the sternal insertion, as in a normal individual On the contracted side, the neck appears quite broad The head is tilted toward the affected side though the chin is not rotated toward the opposite side Open tenotomy will correct the tilt, but the cosmetic result *will be poor Jahss devised the following operation for this abnormality*

Technic (Jahss)—Beginning at the clavicle an incision two inches in length is made between the heads of the sternocleidomastoid muscle toward the mastoid After division the clavicular head is dissected up to the bifurcation with the sternal portion of the muscle All structures in front of the deep cervical fascia are incised back to the anterior margin of the trapezius, and the fascial sheath of the sternal head is completely separated from the *muscle to above the bifurcation The clavicular head is then placed* in the sheath and sutured behind the sternal head and the sheath is closed Tenotomy of the sternal head may or may not be necessary

After Treatment.—After forty-eight hours, a Calot jacket is applied to be retained for five weeks. This is followed by a leather collar which should be worn for a period of six to nine months.

CONGENITAL ELEVATION OF THE SCAPULA

(SPRENGEL S DEFORMITY)

In this condition. the scapula is not only elevated but is also distorted The superior extremity which includes the supraspinatus fossa, is elongated and protruded

Restoration of the scapula to its normal position may be undertaken in children at the age of three years before that age the surgery involved is possibly too extensive Results are better if the treatment is carried out early since the operation becomes more difficult as growth progresses, until ultimately correction is impossible. In neglected cases, overzealous attempts to place the scapula at its proper level may induce *serious neurologic symptoms from tension* on the brachial plexus.

In the Schrock operation, practically the entire scapula is dissected out subperiosteally drawn distally and anchored to a rib at its lower end.

Technic (Schrock)—Beginning at the mid suprascapular area, the incision is curved downward one inch external to the vertebral border and extended two inches below the inferior angle The combined attachments of the *rhomboids, serratus magnus*, and *subscapularis* muscles are severed subperiosteally Similarly the infraspinatus, teres major and minor the supraspinatus, the trapezius muscle on the spine and the structures at the superior margin of the scapula are detached. The nerves and vessels at the supra

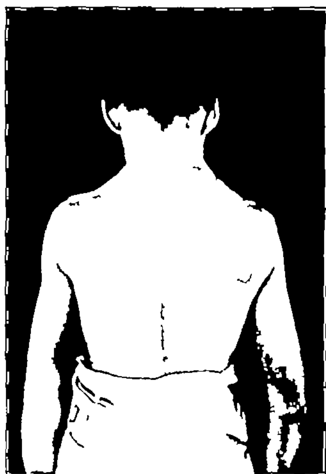


Fig. 1136—End result of bilateral Schrock operation for congenital elevation of scapula (Sprengel's deformity)

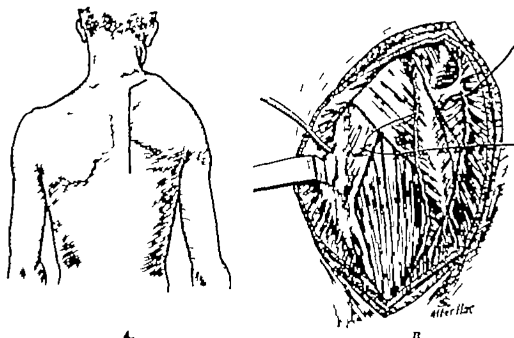
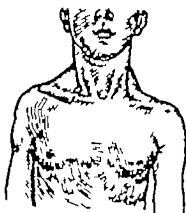


Fig. 1137—Huc procedure for Sprengel's deformity associated with aplasia of clavicle. A Line of skin incision. B Liberation of vertebral border of scapula. Wire passed through hole in scapula just below spine and through an interspinous ligament slightly below level of hole in scapula. Incision temporarily closed (Redrawn from Huc, Georges De L'Adaptation de la Ceinture Scapulaire au Thorax, Vieillemard Imp., Paris, 1923.)

scapular notch should be conserved The chondro-osseous bridge from the vertebrae to the superomedial margin of the scapula is easily removed when present. The prominent portions of the scapula particularly the supraspinatus area, are also resected as well as any prominence of the spine. If the scapula cannot be lowered readily an osteotomy is performed at the base of the acromion. With heavy chromic catgut the inferior border of the scapula is anchored to the lowest rib possible



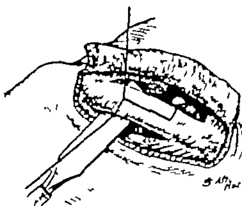


Fig 1138—Same as Fig. 113 Lengthening of clavicle by Z-plastic step cut. (Redrawn from Huc, Georges De L'Adaptation de la Ceinture Scapulaire au Thorax, Vieillemard Imp., Paris, 1932)

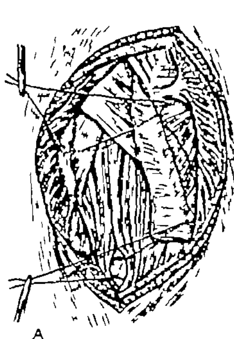




Fig 1139.—Same as Fig. 1137 *A*, Additional hole drilled through lower end of vertebral border of scapula. Wire passed through hole and around seventh rib. *B* Wires pulled taut, with scapula adjusted to normal plane. Lower wire removed after union of osteotomy of clavicle. Routine closure of soft tissues. (Redrawn from Huc, Georges: De L'Adaptation de la ceinture Scapulaire au Thorax, Vieillemard Imp., Paris, 1932.)

After Treatment.—A Velpeau dressing is applied and allowed to remain undisturbed for a period of four weeks.

Huc believes that the terms 'congenital elevation, and ectopia' (mal position or displacement of congenital origin) of the shoulder are inaccurate. The correct classification is (1) scapular aplasia, (2) elevation of the shoulder from congenital aplasia of the clavicle or acquired shortening of the clavicle,

and (3) elevation of the shoulder induced by thoracic deformity (cervical ribs, anomaly of form or number of the ribs)

The treatment of scapular aplasia is unknown Function is seldom affected and the spine seldom deformed

The treatment of elevation of the shoulder must be selected according to the causative agent and the degree of deformity In elevation arising from slight aplasia of the clavicle of congenital origin treatment should be directed toward prevention of spinal deformity, which may arise from faulty posture Complete correction is impossible, since an aplastic clavicle cannot be forced to grow Huc suggests the following operation for the elevation of the shoulder from extreme aplasia of the clavicle.

Technic (Huc) —An inverted L shaped incision is made at the level of the spinal margin of the scapula and the trapezius muscle and plane of the rhomboid are divided After liberation of the superior medial angle of the scapula the posterior scapular artery which is the only vessel likely to cause difficulty is ligated A small hole is then drilled in the scapula 4 cm from the spinal border and just below the spine A bronze aluminum thread is next passed through this hole and through an interspinous ligament at a slightly lower level The ends of the thread are temporarily held in place by means of a clamp The lower angle of the scapula is denuded and the thread drawn through a hole drilled at this point, thence beneath the seventh rib The two ends of the thread are again held with a clamp A flap incision is now made along the anterior border of the middle third of the clavicle, the bone exposed subperiosteally and a Z-plastic cut 3 to 4 cm long made in the bone by means of a Gigli saw The clavicle is elongated to the desired length and the fragments maintained in apposition by a wire suture inserted through drill holes. The scapula is adjusted to the thoracic plane, which is then normal and the wire threads previously inserted are tied. The upper thread, which passes through the axis of movements of the shoulder blade is left in situ. The lower thread on the other hand must be removed when the clavicular fragments have united

CONGENITAL SYNOSTOSIS BETWEEN RADIUS AND ULNA

Congenital synostosis between the radius and ulna usually takes place at the proximal end of the bones, the forearm being fixed in pronation. The abnormality is generally bilateral

Wilkie has noted two types of this condition (1) primary or true radio-ulnar synostosis, in which the upper end of the radius is imperfectly formed and is fused to the ulna for a distance of several centimeters, and (2) synostosis in which the radius is more or less well developed but is dislocated either forward or backward at the elbow and fused to the upper part of the shaft of the ulna In the first type the bony union is of an intimate nature in that the marrow cavities of the radius and ulna are not separated by an intervening layer of compact bone The shaft of the radius arches forward to an unusual degree and in contrast to a slender ulna, is relatively larger and longer An important consideration in the treatment is the fact that the supinator muscles may be defective or absent further the fascial tissues are shortened and altered as to direction and the interosseous membrane is narrower than normal In the second type the fusion is neither so extensive nor so intimate as in the first Wilkie has observed that this type is often uni

lateral and cites several cases wherein other deformities, such as a supernumerary thumb absence of both thumbs, or syndactylism are associated.

As to treatment, Wilkie states that the advisability of surgical intervention is always questionable for primary synostosis, since the bony bridge constitutes but a part of the deformity and a simple division of the union would therefore be futile Gibson concludes that in children removal of the *bony bridge with or without resection of the head of the radius, is a mistake* in adults, however an osteotomy to place the forearm in the mid position is justifiable In the second type wherein the soft structures and bony contour of the radius and ulna are less abnormal the possibility of securing satisfactory function by the treatment described for traumatic synostosis of the radius and ulna (p 573) is more hopeful

Dawson reports the case of a patient with a primary radio-ulnar synostosis for which five separate operations were required before satisfactory supination was obtained *This is sufficient evidence to support the general opinion* that surgical interference is not justified The case is reported in detail because of the rare use of surgery in such lesions. Few patients would have *the fortitude to undergo so many operations.*

The first procedure consisted of removal of the bridge of bone uniting the radius and ulna Through a curved incision on the dorsum of the arm just below the elbow the attachments of the extensor muscles were separated to the posterior border of the ulna. No trace of the supinator brevis muscle was seen but the place normally occupied by this structure was filled with bone. The bridge of bone which was two and one half by one-fourth by three-eighths inches, was removed with a chisel. The head of the radius was irregular in shape and two or three bony prominences were resected. The forearm was forced from extreme pronation through 70 to 90 degrees during this procedure adhesions could be heard snapping in the region of the wrist. A segment of muscle was then stitched between the raw bony surfaces. After one month of physical therapy the radius rotated on the ulna through only 25 degrees, motion apparently being obstructed by a tight ligamentous band, which was thought to be at the distal radio ulnar joint

At the second operation, four weeks after the first a curved incision was made over the dorsum of the wrist the head of the ulna was freed of all ligamentous attachments, and two or three small bony protuberances were resected. No improvement was observed following this procedure.

A third operation eleven months after the second consisted of division of the interosseous membrane and oblique ligament throughout the length of the forearm through a straight incision along the flexor surface. The interosseous membrane was not definite but was composed of isolated bands of fibrous tissue which were strongest at the distal and proximal ends. This operation was followed by slight improvement the total amount of true rotation being about 30 degrees.

At the fourth operation three months after the third the first incision was reopened and the head of the radius was separated from the ulna and surrounding soft tissues, drawn out from the wound and sawed obliquely from above downward and inward leaving the radial tuberosity intact. A fairly large segment of muscular tissue was interposed between the bones. Following this procedure and two or three months of physical therapy 60 degrees of rotation was secured

Since the patient was still not satisfied with the range of motion a fifth operation was carried out Through a seven inch incision over the inner border of the brachioradialis muscle the insertion of the pronator quadratus and all other muscular and ligamentous attachments, with the exception of the insertion of the pronator radii teres muscle were separated from the distal two thirds of the radius. An osteotomy was then performed at the junction of the middle and lower thirds, the distal fragment being rotated toward supination through about 40 degrees. Fixation in this position was secured by a plate and screws. Complete supination was established

From Dawson s experience with one case correction of such a deformity would probably be best accomplished by a two-stage procedure (1) breaking up or excision of the synostosis and removal of the head of the radius, with interposition of either fascia lata or muscle between the radius and ulna, and (2) complete exposure of the shaft of the radius and with the exception of the pronator radii teres muscle division of all muscular attachments, as well as the interosseous membrane throughout the length of the radius, followed by osteotomy and rotation of the distal fragment into supination.

CONGENITAL DISLOCATION OF THE HEAD OF THE RADIUS

Congenital dislocation of the radius is a relatively rare condition but is a definite clinical entity and should be suspected in all old cases of anterior dislocation of the head of the radius without an associated fracture of the ulna. The roentgenographic picture is fairly characteristic. The head of the radius is dislocated anteriorly the radial shaft appears too long, and the the head is dome shaped with no depression for articulation with the capitellum. Occasionally a small dense area of ossification in the tissues overlying the head of the radius is present. The radius and ulna are not fused

Clinically the head of the radius is displaced forward is freely movable and cannot be replaced in its normal position

White examined a patient with congenital dislocation of the elbow under the fluoroscope Flexion of the elbow caused the head of the radius to slide over the anterior surface of the humerus until the flexion was blocked by the pressure of the humerus on an ossified area lying over the head of the radius. In full extension the head of the radius dislocated over the anterior surface of the capitellum when the forearm was rotated a gap was visible between the coronoid and the radial head

Treatment.—Excision of the radial head (p 494)

MADELUNG S DEFORMITY

Madelung s deformity is a spontaneous deformity of the wrist wherein the lower extremity of the radius is angulated forward and the head of the ulna displaced backward. *On inspection* the condition is apparently an anterior subluxation of the wrist joint with dorsal dislocation of the distal radio-ulnar joint *roentgenograms* however reveal no change in the relation of the articular surfaces of the bones of the wrist. As the abnormality may be caused by latent rickets or an indefinite process such as epiphysitis operation is deferred as a rule until full growth is attained and the epiphysis has completely fused The deformity may be sufficiently severe to warrant treatment before the epiphysis has fused

In our experience correction of the angulation of the radius has been su ficient to produce a satisfactory functional result and a fairly good cosmet appearance In adults, this procedure may be combined with Darrach s res tion of the distal end of the ulna (p 597), in children, Milch's cuff resecti (p 598) might be satisfactorily combined with a simple osteotomy of t radius.

Technic.—The lateral aspect of the wrist is incised longitudinally a d tance of one half to one inch exposing the radius one inch proximal to t *articular surface (p 160) A transverse osteotomy is carried out at th* point and the wrist is hyperextended until anatomic alignment is restored

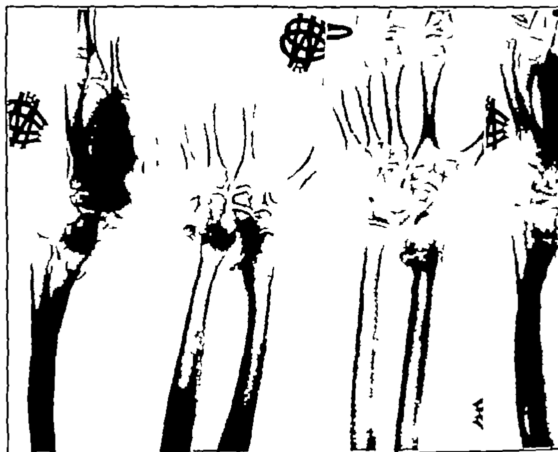


Fig. 1148.—A Madelung s deformity, before and after osteotomy and correction of angul tion of radius. Note ma ked improvement in alignment of carpus with forearm in both anter posterior and lateral views.

After Treatment.—A sugar tong plaster bandage or any of the splints use for Colles fracture is applied the wrist being immobilized in moderate exte sion, and the lower fragment in correct alignment. A roentgenogram mu be made at once to confirm the position of *the fragments in the cast,* and r peated at the end of one week. The cast or splint is removed after three week for inspection of the wrist and a further roentgenogram If the relation o the fragments is unchanged the same molded cast is replaced and worn fo *an additional three weeks.*

Technic (Lowman).—A longitudinal incision is made between the flexo and extensor tendons of the carpus at the ulnar border *Blunt dissection*

then carried through the wrist dorsal to the radius and ulna and ventral to the pronator quadratus muscle to an incision on the radial border of the wrist. A large hole is then drilled through the radius one inch above the joint in a palmar and ulnar direction By means of a fascia carrier, a strip of fascia lata from the thigh eight inches in length is inserted through the drill hole thence passed dorsally through the interosseous membrane around the ulna and across the palmar surface and sutured to the opposite end Five months later the forward angulation of the radius is corrected by an osteotomy

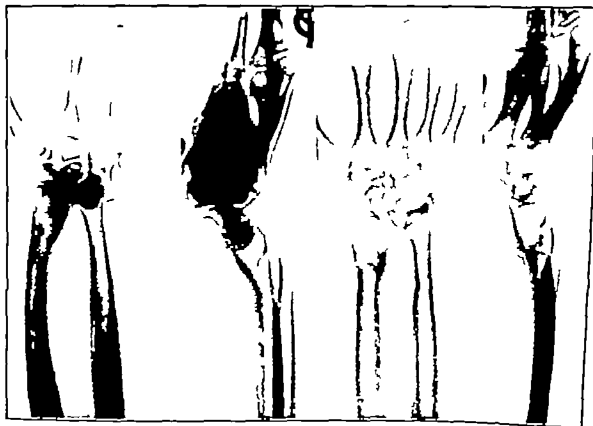


Fig. 1141 —Same patient as shown in Fig 1140 Opposite wrist before and after [illegible] of radius. Marked improvement in function of wrist, as well as in cosmetic [illegible] Distal end of ulna prominent. Additional surgery advised to further improve [illegible] wrist and slight instability of distal radio-ulnar joint.

ARTHROGRYPOSIS MULTIPLEX CONGENITA

Congenital fibrous ankylosis affects many joints, producing [illegible] deformities. Clubfeet incomplete extension of the knees and elb[illegible] club hands, analogous to clubfeet are some of the manifestatio[illegible] th[illegible] abnormality The condition may involve only the lower extre[illegible] may include practically all the large joints. In the feet, the fibro[illegible] associated with an equinovarus deformity necessitating treat[illegible] the lines prescribed for congenital clubfeet the deformity howeve[illegible] resistant to treatment and the tendency to recurrence is pr[illegible] The prognosis is poor regardless of the treatment. Conservative [illegible] of the associated contractures should be instituted as early [illegible] In the resistant and older cases operative measures are [illegible] knee osteotomy may be indicated in a few cases and at the [illegible] reconstruction with modified arthroplasties (p 1113) at the [illegible] required. At the wrist resection (p 1049) arthroplasties (p 111[illegible]

erations (p 987) may be performed the fixed pronation being corrected in every case Operative measures are often deferred until late childhood adolescence or maturity according to the indications in the individual case

References

Asymmetrical Development

Campbell Willis C.: Congenital Hypertrophy Report of a Case with Diffuse Neurofibromatosis, Surg Gynec. Obst. 36: 090 1923.

Peabody, C. W Hemihypertrophy and Hemiatrophy; Congenital Total Unilateral Somatic Asymmetry J Bone & Joint Surg 18 466, 1936.

Peremans G An Unusual Case of Congenital Asymmetry of the Pelvis and Lower Extremities, J Bone & Joint Surg. 5: 331 1923

Porzan A: Congenital Hypertrophy of Both Feet and Left Leg; Surgical Therapy of Case, Gior med. d Alto Adige 9 225, 1937

Rogers, L. Macrodactylia in a Child Due to Neurofibromatosis (Elephantiasis Neuromatosa) Brit J Surg 16 684 1929

Abnormalities of the Fingers Toes and Feet

Blumenfeld, I., Kaplan, N., and Hicks E. O: The Conservative Treatment of Congenital Talipes Equinovarus, J Bone & Joint Surg 28 765 1946.

Brockman E. P: Congenital Club-Foot, London, 1930 John Wright & Sons, Ltd

Forrester Brown M The Treatment of Congenital Equinovarus (Club-Foot) J Bone & Joint Surg 17 661 1935

Gareeau G J: Anterior Tibial Tendon Transposition in Recurrent Congenital Club-Foot, J Bone & Joint Surg 22 932, 1940

Gareeau, G J., and Manning, K R. Transposition of the Anterior Tibial Tendon in the Treatment of Recurrent Congenital Club-Foot J Bone & Joint Surg 29 1044 1947

Goodwin F C., and Swisher F M: The Treatment of Congenital Hyperextension of the Fifth Toe J Bone & Joint Surg. 25 193, 1943.

Horwitz, M. T: Unusual Hallux Varus Deformity and Its Surgical Correction, J Bone & Joint Surg 19 828 1937

Kanavel, A B.: Congenital Malformations of the Hands, Arch. Surg 25 282, 1932.

Kite J H. The Treatment of Congenital Club-Feet Surg Gynec. Obst. 61 190, 1935.

Lantzounis, L. A.: Congenital Subluxation of the Fifth Toe and Its Correction by Periosteocapsuloplasty and Tendon Transplantation J Bone & Joint Surg 22 147 1940

Lapidus, P W Transplantation of the Extensor Tendon for Correction of the Overlapping Fifth Toe J Bone & Joint Surg 24 555, 1942.

Macey H. B. Clubfoot, S. Clin. North America 17 1231 193

McElvenny R. T: *Hallux Varus Quart. Bull., Northwestern Univ M School 15 277* 1941

Ober F R. An Operation for the Relief of Congenital Equino-Varus Deformity J Bone & Joint Surg 2 558 1920

O'Donoghue D H Controlled Rotation Osteotomy of the Tibia, South. M J 33 1145, 1940

Peabody C. W Discussion of: Transposition of the Anterior Tibial Tendon in the Treatment of Recurrent Congenital Club-Foot G J Gareeau J Bone & Joint Surg 29 1048 1047

Peabody C W., and Muro Felipe Congenital Metatarsus Varus J Bone & Joint Surg 15 171 1933.

Sell, L. S Tibial Torsion Accompanying Congenital Club-Foot J Bone & Joint Surg 23 561 1941

Sloane David Congenital Hallux Varus. Operative Correction, J Bone & Joint Surg 17 209 1935

Absence Defect or Congenital Pseudoarthrosis of the Long Bones

Albee F H Formation of Radius Congenitally Absent, Ann. Surg 87 105, 1928.

Barber C G Congenital Bowing and Pseudarthrosis of the Lower Leg Manifestations of von Recklinghausen's Neurofibromatosis, Surg Gynec. Obst. 69 618, 1939.

Bardenheuer, B: Vorstellung von 4 Patienten, an welchen die totale Resektion des ganzen Hüftgelenkes ausgeführt worden war Ber ü. d. Verhandl. d. deutsch. Gesellsch. f. Chir 23 105 1894

Boyd, H. B. Congenital Pseudarthrosis. Treatment by Dual Bone Grafts, J Bone & Joint Surg 23 49 1941

Camurati Mario: Le pseudartrosi congenite della tibia, Chir d. Org di Movimento 15 1, 1930.
Colonna P C: Congenital Pseudarthrosis of the Leg Three Cases Treated by Massive Bone Graft J A M A 103: 2019 1934
Compere E. L. Localized Osteitis Fibrosa in the New Born and Congenital Pseudarthrosis, J Bone & Joint Surg 18 513 1936
Freund, Ernst: Congenital Defects of Femur, Fibula and Tibia, Arch. Surg 33 349 1936.
Green W T., and Rudo, N Pseudarthrosis and Neurofibromatosis, Arch Surg 46 639 1943.
Hallock, Halford The Use of Multiple Small Bone Transplants in the Treatment of Pseudarthrosis of the Tibia of Congenital Origin or Following Osteotomy for Correction of Congenital Deformity J Bone & Joint Surg 20 648 1938
Henderson, M S Congenital Pseudarthrosis of the Tibia, J Bone & Joint Surg 10 483 1928.
Henderson M S., and Clegg R S Pseudarthrosis of Tibia. Report of One Case Proc. Staff Meet Mayo Clin 16 60 1941
Inglis Keith: The Pathology of Congenital Pseudarthrosis of the Tibia, J Coll. Surgeons Australasia 1 104 1928.
Kato, Katsuji: Congenital Absence of Radius, J Bone & Joint Surg 6 589 1924
Kite J H: Congenital Pseudarthrosis of Tibia and Fibula South. M J 34 1021, 1941
Lewin, Philip: Congenital Absence or Defects of Bones of Extremities, Am J Roentgenol 41: 431 191
McFarland, Bryan: Birth Fracture of the Tibia Brit J Surg 27 706 1939
Makin A S.: Congenital Pseudarthrosis of Tibia Treated by Twin Grafts, Proc. Roy Soc. Med. 38 71 1944
Moore B. H: Some Orthopaedic Relationships of Neurofibromatosis, J Bone & Joint Surg 23 109 1941
Moore J R.: Pseudarthrosis of the Tibia and Fibula in Children, J Int. Coll Surg 9 7 1946
Ollerenshaw R Congenital Defects of the Long Bones of the Lower Limb; A Contribution to the Study of Their Causes, Effects and Treatment, J Bone & Joint Surg 7 528 1925
Putti, V: The Treatment of Congenital Absence of the Tibia or Fibula Internat. Abstr Surg 50 42, 1930 (Abst. from Chir d org di movimento 7: 513 1929)
Ryerson, E. W Quoted by Kato (see above)
Scaglietti O: Il Perone in Posto della Tibia, Boll. e mem. Soc. Emiliano-Romagnola di Chir 2 No. 2, 1936.
Scott, C. R.: Congenital Pseudarthrosis of the Tibia, Am J Roentgenol. 42 104 1939
Smith, A DeF: Use of Homologous Bone Grafts in Cases of Osteogenesis Imperfecta Arch. Surg 34 687 1937
Stenport Kurt Congenital Pseudarthrosis of the Leg Acta Orthop. Scandinav 9 181 1938
Wade R. B. The So-Called Congenital Pseudarthrosis of the Tibia, J Coll. Surgeons, Australasia 1 181 1928
William R. E.: Two Congenital Deformities of the Tibia Congenital Angulation and Congenital Pseudarthrosis Brit J Radiology 16 371 1943.
Wilson, P D A Simple Method of Two Stage Transplantation of the Fibula for Use in Cases of Complicated and Congenital Pseudarthrosis of the Tibia, J Bone & Joint Surg 23 639 1941

Congenital Dislocation of the Hip and Knee

Abbott, L. C.: The Treatment of Old Congenital Dislocation of the Hip Arch. Surg 12 983, 1926.
Adams, Z. B. The Treatment of Congenital Dislocation of the Hip as Practiced by Professor Denucé at Bordeaux, France J Bone & Joint Surg 20 523 1922.
Albee, F H.: The Bone Graft Wedge. Its Use in the Treatment of Relapsing Acquired, and Congenital Dislocation of the Hip New York M. J 102 433 1915
—: Bone Graft Surgery Philadelphia 1915 W B Saunders Co
— Injuries and Diseases of the Hip New York 1937 Paul B Hoeber Inc.
Allison, N The Open Operations for Congenital Dislocation of the Hip, The Robert Jones Birthday Volume, London 1928 Oxford University Press, p. 97
Blount, W P: The Peg Leg Cast, J Bone & Joint Surg 13 107, 1931
Blount W P Blade Plate Internal Fixation for High Femoral Osteotomies, J Bone & Joint Surg 25 319 1943.
Calot, F Treatment of Congenital Luxations and Subluxations of the Hip and Their Recurrence, Monde méd., Paris 44 1 1934
Chandler P A. Congenital Dislocation of the Hip S. Clin. North America 13 1141 1933
Cole, W H: The Open Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17 18 1935

Colonna, P C.: Congenital Dislocation of the Hip in Older Subjects, J Bone & Joint Surg. 14: 277, 1932.

— An Arthroplastic Operation for Congenital Dislocation of the Hip—A Two Stage Procedure, Surg Gynec. Obst. 63: 777, 1936

Colonna, P C. *Arthroplasty of the Hip for Congenital Dislocation in Children, J Bone & Joint Surg 29: 711, 1947*

Compere E L., and Phemister D B.: The Tibial Peg Shelf in Congenital Dislocation of the Hip, J Bone & Joint Surg 17: 60 1935.

Compere L. L., and Schnute W J: *Treatment of Congenital Dislocation of the Hip*, J Bone & Joint Surg 28 555 1946

Conn, H. R.: *A New Method of Operative Reduction for Congenital Luxation of the Patella* J Bone & Joint Surg 7 370 1925.

Dickson, F D: The Operative Treatment of Old Congenital Dislocation of the Hip, J Bone & Joint Surg 6 262, 1924.

—: The Shelf Operation in the Treatment of Congenital Dislocation of the Hip, Surg Gynec. Obst. 55: 81 1932.

—: Davis Method for Closed Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 7: 873, 1925.

—: The Shelf Operation in the Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17 43, 1935

Epstein G J and Epstein, N B. König's Operation in the Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17 309 1935.

Freiberg, A. H.: Congenital Luxation of the Hip, J Bone & Joint Surg 17 1 1935

Freiberg, J A Early Diagnosis and Treatment of Congenital Dislocation of the Hip, J A. M. A 102: 89 1934

Gaenslen F J: The Schanz Subtrochanteric Osteotomy for Irreducible Dislocation of the Hip J Bone & Joint Surg. 17 76 1935.

Galland W I: The Bifurcation Operation, Surg Gynec. Obst. 50: 90 1930

Galloway H. P H.: The Open Operation for Congenital Dislocation of the Hip, J Bone & Joint Surg 2: 390 1920

—: The Open Operation for Congenital Dislocation of the Hip, Surg Gynec. Obst. 37 674, 1923.

—: The Open Operation for Congenital Dislocation of the Hip; Special Reference to Results, J Bone & Joint Surg 8: 539, 1926.

Ghormley Ralph K.: Use of the Anterior Superior Spine and Crest of Ilium in Surgery of the Hip Joint, J Bone & Joint Surg 13 784 1931.

Gill A. B. Operation for Old or Irreducible Congenital Dislocation of the Hip, J Bone & Joint Surg 10 696, 1928.

—: Plastic Construction of an Acetabulum in Congenital Dislocation of the Hip—The Shelf Operation, J Bone & Joint Surg 17 48 1935

—: An Evaluation of Present Day Methods of Dealing With Congenital Dislocation of the Hip, J Bone & Joint Surg 18: 487 1936.

Gill A. B.: End Results of Bloodless Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 25 1 1943.

Groves, E W H.: Some Contributions to the Reconstructive Surgery of the Hip, Brit. J Surg 14 486 1926-27

—: The Treatment of Congenital Dislocation of the Hip-Joint, With Special Reference to Open Operative Reduction, The Robert Jones Birthday Volume London, 1928, Oxford University Press, p. 73.

Haas, J: Bifurcation Operation of Lorenz. Twenty-Sixth Report of Progress in Orthopedic Surgery p. 24. (Abst. from Ztschr f. orthop. Chir 43 481 1924.)

Haas, S. L.: The Treatment of Congenital Dislocation of the Hip-Joint, Am. J Surg 13 235, 1931

—: Pin Fixation in Dislocation of the Hip Joint, J Bone & Joint Surg 14: 346, 1932.

Howorth, M B.: Shelf Stabilization of the Hip, J Bone & Joint Surg 17 945 1935.

Howorth M. B Congenital Dislocation of the Hip, Ann. Surg 125 216 1947

Howorth, M. B., and Smith, H. W: Congenital Dislocation of Hip Treated by Open Operation, J Bone & Joint Surg 14: 299 1932

Jones, Ellis: The Operative Treatment of Irreducible Paralytic Dislocation of the Hip Joint, J Orthop. Surg 2 183, 1920.

Jones, Sir Robt., and Lovett, Robt. W: *Orthopedic Surgery New York, 1924* Wm. Wood & Co.

Kidner F C.: Open Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 13 799 1931.

—: Comparative Analysis of the Results of Open and Closed Reductions in Congenital Dislocation of the Hip J Bone & Joint Surg 17 25, 1935

Krida, Arthur Congenital Dislocation of the Hip; the Effect of Anterior Distortion; A Procedure for Its Correction, J Bone & Joint Surg 10: 594, 1928.

— Congenital Dislocation of the Hip Joint, Am J Surg 6 183 1929
— A New Departure in the Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 13 811, 1931
Lange B.: Closed Reduction of Congenital Dislocation of the Hip München med Wchnschr 51 8.2, 1904
Lange Fritz Congenital Dislocation of the Hip, München. med Wchnschr 75 2001 1928
—: Need for Improvement of Therapeutic Methods in Congenital Dislocation of Hip Arch di ortop. 49 273, 1933
Lange M: Bloodless Treatment of Congenital Dislocation of Hip Prakt. Arzt 16 120 1931
Leveuf J: Primary Congenital Subluxation of the Hip J Bone & Joint Surg 29 149 194
Lorenz, Adolf: A New Method of Treatment of Irreducible Acquired or Congenital Hip Dislocations New York M J 117 130 1923.
Lowman, C. L.: The Double-Leaf Shelf Operation for Congenital Dislocation of the Hip J Bone & Joint Surg 13: 511 1931
Ludloff K.: The Open Reduction of the Congenital Hip Dislocation by an Anterior Incision, Am. J Orthop. Surg 10 438 1913
McCarroll H. R., and Crego C. H., Jr: Primary Anterior Dislocation of the Hip J Bone & Joint Surg 21: 648 1939
McCarroll H. R., and Schwartzmann, J R.: Lateral Dislocation of the Patella. Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon, J Bone & Joint Surg 27 446, 1945
MacAusland W R.: The Treatment of Congenital Dislocation of the Hip by Open Operation, Surg Gynec. Obst. 47 697 1928.
Massart, Raphael The Modified Bifurcation Operation for the Treatment of Painful Congenital Dislocation of the Hip, J Bone & Joint Surg 13 33 1931
Mayer, Leo Congenital Anterior Subluxation of the Knee, Am. J Orthop. Surg 10 411 1913.
McFarland, B. L. Congenital Dislocation of the Knee J Bone & Joint Surg 11 281 1929
Mercer Walter: Orthopaedic Surgery Baltimore 1936 Wm. Wood & Co
Moeller N., Jr Anatomical Bases for Treatment of Congenital Luxation of the Hip and Its Results, Presse méd. belge Bruxelles 61 125 1909
Mueller F A New Primary Position in the Bloodless Treatment of Congenital Hip Joint Dislocation, J A. M. A 48 282, 1907
Mumford E. B.: Congenital Dislocation of the Patella. Case Report With History of Four Generations, J Bone & Joint Surg 29 1083, 1947
Nachlas, I. H Bucket Handle Acetabuloplasty for Dislocation of the Hip. (Personal communication.)
Ober F R.: Shelf Operation to Relieve Persistent Dislocation of the Hip J Bone & Joint Surg 17 73 1935.
Ponseti Ignacio Pathomechanics of the Hip After the Shelf Operation J Bone & Joint Surg 28 229 1946
Putti V Congenital Dislocation of the Hip, Surg Gynec. Obst. 42 449 1926.
— Early Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 11 798 1929
Putti, V., and Zanoli R.: Forty Seventh Report of Progress in Orthopedic Surg., p. 1. (Abst. from Chir d org di movimento 16 1 1931)
Reich, R. S. The Bifurcation Operation for the Treatment of Irreducible Dislocations of the Hip Joint, J Bone & Joint Surg 7 598 1925
Ridlon, J Congenital Dislocation of the Hip Rhode Island M. J 16 135, 1933
Sherman, H. M. Congenital Dislocation of the Hip J A. M. A. 44 31, 1905
— Congenital Dislocation of the Hip a Rational Method of Treatment, Surg Gynec. Obst. 18 62, 1914
Smith A. B.: Shelving Operation in Treatment of Neglected or Irreducible Congenital Dislocated Hip Ann. Surg 106 9* 1937
— Shelving Operation as Adjunct to Open Reduction in Congenital Dislocated Hip and Its Use in Paralytic and Pathologic Dislocations Ann. Surg 106 278 1937
Steindler, Arthur Congenital Dislocation of the Knee, Abt s Pediatrics, Vol. 5 p. 420, Philadelphia, 1924 W B. Saunders Co.
—: A Textbook of Operative Orthopedics, New York 1925 D Appleton & Co.
Steindler A., Kulowski J and Freund, E.: Congenital Dislocation of the Hip Statistical Analysis, J A. M. A. 104 302, 1935
Stewart, S. P: The Physiological Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17 11 1935
Swett Paul P: An Operation for the Reduction of Certain Types of Congenital Dislocation of the Hip, J Bone & Joint Surg 10 675 1928
Werndorff Robert Axillary Abduction in the Treatment of Congenital Dislocation of the Hip Ztschr f. orthop Chir., Stuttgart 13 765 1904.

Colonna, P C.: Congenital Dislocation of the Hip in Older Subjects, J Bone & Joint Surg 14: 277 193_
— An Arthroplastic Operation for Congenital Dislocation of the Hip—A Two Stage Procedure, Surg Gynec. Obst. 63 777, 1936.
Colonna P C.: Arthroplasty of the Hip for Congenital Dislocation in Children, J Bone & Joint Surg 29: "11, 1947
Compere E. L., and Phemister D B.: The Tibial Peg Shelf in Congenital Dislocation of the Hip J Bone & Joint Surg 17: 60 1935
Compere L. L., and Schnute W J Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 28 555, 1946.
Conn, H. R: A New Method of Operative Reduction for Congenital Luxation of the Patella, J Bone & Joint Surg 7: 370 192_
Dickson, F D: The Operative Treatment of Old Congenital Dislocation of the Hip, J Bone & Joint Surg 6 262, 1924.
—: The Shelf Operation in the Treatment of Congenital Dislocation of the Hip, Surg Gynec. Obst. 55 81 1932.
—: Davis Method for Closed Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 7 873, 1925
— The Shelf Operation in the Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17 43, 1935
Epstein, G J., and Epstein, N S.: König s Operation in the Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg 17: 300 193_
Freiberg A H: Congenital Luxation of the Hip, J Bone & Joint Surg 17 1, 1935.
Freiberg, J A: Early Diagnosis and Treatment of Congenital Dislocation of the Hip, J A. M. A 102: 89 1934
Gaenslen, F J: The Schanz Subtrochanteric Osteotomy for Irreducible Dislocation of the Hip, J Bone & Joint Surg 17 76, 1935.
Galland W I: The Bifurcation Operation, Surg Gynec. Obst. 50 90 1930.
Galloway H P H.: The Open Operation for Congenital Dislocation of the Hip, J Bone & Joint Surg 2 390 19"0.
— The Open Operation for Congenital Dislocation of the Hip, Surg Gynec. Obst. 37 074 1923.
—: The Open Operation for Congenital Dislocation of the Hip Special Reference to Results, J Bone & Joint Surg 8 539 1926.
Ghormley Ralph K.: Use of the Anterior Superior Spine and Crest of Ilium in Surgery of the Hip Joint, J Bone & Joint Surg 13 784 1931
Gill A B: Operation for Old or Irreducible Congenital Dislocation of the Hip J Bone & Joint Surg 10 696, 19"8.
—: Plastic Construction of an Acetabulum in Congenital Dislocation of the Hip—The Shelf Operation, J Bone & Joint Surg 17 48 1935.
—: An Evaluation of Present Day Methods of Dealing With Congenital Dislocation of the Hip J Bone & Joint Surg 18: 487 1936.
Gill A. B.: End Results of Bloodless Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 25 1 1943.
Groves, E. W H.: Some Contributions to the Reconstructive Surgery of the Hip, Brit. J Surg 14 486 1926-27
—: The Treatment of Congenital Dislocation of the Hip-Joint, With Special Reference to Open Operative Reduction, The Robert Jones Birthday Volume London, 1928, Oxford University Press, p. 73.
Haas, J: Bifurcation Operation of Lorenz. Twenty-Sixth Report of Progress in Orthopedic Surgery p. "4 (Abst. from Ztschr f. orthop. Chir 43: 451 19"4)
Haas, S. L.: The Treatment of Congenital Dislocation of the Hip-Joint Am. J Surg 13: 235 1931
—: Pin Fixation in Dislocation of the Hip Joint J Bone & Joint Surg 14 346, 1932.
Howorth M B.: Shelf Stabilization of the Hip J Bone & Joint Surg 17 945, 1935.
Howorth, M. B. Congenital Dislocation of the Hip, Ann. Surg 125 "16, 1947
Howorth, M. B., and Smith, H. W: Congenital Dislocation of Hip Treated by Open Operation, J Bone & Joint Surg. 14: 299 1932.
Jones, Ellis: The Operative Treatment of Irreducible Paralytic Dislocation of the Hip Joint, J Orthop. Surg 2 183, 1920.
Jones, Sir Robt. and Lovett Robt. W Orthopedic Surgery New York, 19"3 Wm. Wood & Co.
Kidner F C.: Open Reduction of Congenital Dislocation of the Hip, J Bone & Joint Surg 13 799 1931.
—: Comparative Analysis of the Results of Open and Closed Reductions in Congenital Dislocation of the Hip, J Bone & Joint Surg 17: 25, 1935.
Krida, Arthur Congenital Dislocation of the Hip the Effect of Anterior Distortion; A Procedure for Its Correction, J Bone & Joint Surg 10: 594, 1928

— Congenital Dislocation of the Hip Joint Am J Surg 6 18. 1929
—: A New Departure in the Treatment of Congenital Dislocation of the Hip J Bone & Joint Surg 13 811, 1931
Lange R.: *Closed Reduction of Congenital* Dislocation of the Hip, München. med Wchnschr 51 8 2, 1904
Lange Fritz: Congenital Di location of the Hip München. med Wchnschr 75 2001 1928
— Need for Improvement of Therapeutic Methods in Congenital Dislocation of Hip Arch di ortop. 49 2 3, 1933
Lange M Bloodless Treatment of Congenital Dislocation of Hip Prakt. Arzt 16 129 1931
Leveuf J Primary Congenital Subluxation of the Hip J Bone & Joint Surg 29 149 194
Lorenz, Adolf: A New Method of Treatment of Irreducible Acquired or Congenital Hip Dislocations New York M J 117 130 1923.
Lowman, C L.: The Double-Leaf Shelf Operation for Congenital Dislocation of the Hip *J Bone & Joint Surg 13 511, 1931*
Ludloff K: The Open Reduction of the Congenital Hip Dislocation by an Anterior Incision, Am. J Orthop. Surg 10 438 1913
McCarroll H R., and Crego C. H., Jr: Primary Anterior Dislocation of the Hip J Bone & Joint Surg 21: 648, 1939
McCarroll, H R., and Schwartzmann J R Lateral Dislocation of the Patella. Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon, J Bone & Joint Surg 27 446 1945.
MacAusland W R.: The Treatment of Congenital Dislocation of the Hip by Open Operation, Surg Gynec. Obst. 47 697 1928.
Massart, Raphael: The Modified Bifurcation Operation for the Treatment of Painful Congenital *Dislocation of the Hip J Bone & Joint Surg 13 33, 1931.*
Mayer Leo Congenital Anterior Subluxation of the Knee Am. J Orthop. Surg 10 411 1913.
McFarland, B. L. Congenital Dislocation of the Knee, J Bone & Joint Surg 11 281 1929
Mercer Walter Orthopaedic Surgery Baltimore 1936 Wm. Wood & Co
Moeller N., Jr: Anatomical Bases for Treatment of Congenital Luxation of the Hip and Its Results, Presse méd. belge Bruxelles 61 123 1909
Mueller F *A New Primary Position in the Bloodless Treatment of Congenital Hip Joint* Dislocation, J A. M. A 48 282, 1907
Mumford, E. B.: Congenital Dislocation of the Patella. Case Report With History of Four Generations J Bone & Joint Surg 29 1083, 1947
Nachlas, I. W Bucket Handle Acetabuloplasty for Dislocation of the Hip. (Personal communication.)
Ober F R. Shelf Operation to Relieve Persistent Dislocation of the Hip J Bone & Joint Surg 17 73 1935
Ponseti Ignacio Pathomechanics of the Hip After the Shelf Operation, J Bone & Joint Surg 28 229 1946
Putti, V Congenital Dislocation of the Hip Surg Gynec. Obst. 42 449 1926.
—: *Early Treatment of Congenital Dislocation of the Hip, J Bone & Joint Surg* 11 798 1929
Putti, V., and Zanoli, R. Forty-Seventh Report of Progress in Orthopedic Surg., p. 1 (Abst from Chir d org di movimento 16 1 1931)
Reich, R. S. *The Bifurcation Operation for the Treatment of Irreducible Dislocations of the* Hip Joint, J Bone & Joint Surg 7 598 1925
Ridlon, J Congenital Dislocation of the Hip Rhode Island M. J 16 135 1933
Sherman, H. M Congenital Dislocation of the Hip J A. M A. 44 31 1905
— Congenital Dislocation of the Hip a Rational Method of Treatment Surg Gynec. Obst. 18 62, 1914.
Smith, A. R. Shelving Operation in Treatment of Neglected or Irreducible Congenital Dislocated Hip Ann. Surg 106 92, 1937
— Shelving Operation as Adjunct to Open Reduction in Congenital Dislocated Hip and Its Use in Paralytic and Pathologic Dislocations, Ann Surg 106 278 1937
Steindler, Arthur Congenital Dislocation of the Knee, Abt s Pediatrics, Vol. 5 p. 420 Philadelphia, 1924 W B. Saunders Co
—: A Textbook of Operative Orthopedics, New York, 1925 D Appleton & Co.
Steindler A., Kulowski, J., and Freund, E. Congenital Dislocation of the Hip; Statistical Analysis, J A M. A. 104 802 1935
Stewart, S. F *The Physiological Treatment of Congenital Dislocation* of the Hip, J Bone & Joint Surg 17 11 1935
Swett, Paul P: An Operation for the Reduction of Certain Types of Congenital Dislocation of the Hip J Bone & Joint Surg 10 675 1928.
Werndorff, Robert Axillary Abduction in the Treatment of Congenital Dislocation of the Hip Ztschr f. orthop Chir., Stuttgart 13 765 1904.

Coxa Vara

Barr J S.: Congenital Coxa Vara, Arch. Surg 18 1909 1920
Duncan G A.: Congenital and Developmental Coxa Vara, Surgery 3 741 1938
Fairbank H. A. T: Infantile or Cervical Coxa Vara, The Robert Jones Birthday Volume, London, 1928 Oxford University Press, p. 225.
Peabody C. W: Subtrochanteric Osteotomy in Coxa Vara, Arch. Surg 46 43 1943.
Sorrell, L. Congenital Coxa Vara. Cuneiform Resection of the Cervicodiaphyseal Angle and the Replacement of the Resected Corner in Reversed Position. Excellent Result, Internat. Abstr Surg 66 160, 1938. (Abst. from Mem. Acad. de chir 63 739 1937.)
Zadek I.: Congenital Coxa Vara, Arch. Surg 30 62, 1935.

Abnormalities of the Vertebrae

Burns, B. H Two Cases of Spondylolisthesis, Proc. Roy Soc. Med. 25 571 1932.
Chandler F A Lesions of the 'Isthmus' (Pars Interarticularis) of the Laminae of the Lower Lumbar Vertebrae and Their Relation to Spondylolisthesis, Surg Gynec. Obst. 53 273, 1931
Compere, E. L.: Excision of Hemivertebrae for Correction of Congenital Scoliosis, J Bone & Joint Surg. 14 555, 1932.
Dittrich, R. J: Lumbosacral Spina Bifida Occulta, Surg Gynec. Obst. 53 378 1931.
Jenkins, J A: Spondylolisthesis, Brit. J Surg 24 80 1936
Mercer, W: Spondylolisthesis: With a Description of a New Method of Operative Treatment and Notes of Ten Cases, Edinburgh M. J 43 545 1936.
Meyerding, H W: Spondylolisthesis, J Bone & Joint Surg 13 39 1931
Meyerding H W: Low Backache and Sciatic Pain Associated With Spondylolisthesis and Protruded Intervertebral Disc Incidence Significance and Treatment (Symposium) J Bone & Joint Surg 23 461 1941
Royle N D: The Operative Removal of an Accessory Vertebra M. J Australia 1 467 1928.
Speed, Kellogg: Spondylolisthesis; Treatment by Anterior Bone Graft, Arch. Surg 37 175 1938.
Von Lackum H L., and Smith A.DeF: Removal of Vertebral Bodies in the Treatment of Scoliosis Surg Gynec. Obst. 57 250 1933.
Wilson, J C.: Surgical Treatment of Traumatic Spondylolisthesis, J Bone & Joint Surg 9 346, 1927

Torticollis

Chandler F A., and Altenberg A.: Congenital Muscular Torticollis, J A. M. A. 125 476 1944
Dickson, J A.: The Treatment of Torticollis S. Clin. North America 17 1349 1937
Feil: Seventeenth Report of Progress in Orthopedic Surgery p. 1 (Abst. from Presse méd 29 515 1921)
Hauser E. D W: The Treatment of Torticollis, S Clin. North America 16 231 1936.
Jahss, S. A. Torticollis J Bone & Joint Surg 18 1065 1936
Meyerding H W: Congenital Torticollis, J Orthop. Surg 3 91 1921

Congenital Elevation of the Scapula

Horwitz A. E.: Congenital Elevation of the Scapula—Sprengel's Deformity Am. J Orthop. Surg 6 260 1908.
Huc, Georges De L Adaptation de la Ceinture Scapulaire au Thorax Essai d Anatomie de Physiologie de Pathologie et de Therapeutique Paris 1924 No. 403 Viellemard Imp
Schrock, R. D.: Congenital Elevation of the Scapula, J Bone & Joint Surg 8 270 1926.
— Congenital Elevation of the Scapula, Nelson's New Loose Leaf Surgery, Vol. III New York, 1935 Thomas Nelson & Sons, p 179 M
Whitman, Armitage: Congenital Elevation of Scapula and Paralysis of Serratus Magnus Muscle J A M. A 99 1332 1932.

Radio-Ulnar Synostosis

Cohn, B. N E.: Congenital Bilateral Radio-Ulnar Synostosis, J Bone & Joint Surg 14 404 1932.
Dawson, H. G W: A Congenital Deformity of the Forearm and Its Operative Treatment. Brit. M. J 2 833, 1912
Fahlstrom, Stanley Radio-Ulnar Synostosis. Historical Review and Case Report, J Bone & Joint Surg 14 395 1932.
Gibson Alexander: A Critical Consideration of Congenital Radio-Ulnar Synostosis, With Special Reference to Treatment, J Bone & Joint Surg 5: 299 1923.
Wilkie D P D: Congenital Radio-Ulnar Synostosis, Brit. J Surg 1 366, 1913 14

Miscellaneous

Adson, A W., and Coffey J R.: Cervical Rib, Ann. Surg 85: 839, 1927
Blair, D M., Davies F., and McKissock, W: The Etiology of the Vascular Symptoms of Cervical Rib Brit J Surg 22: 406, 1934 35
Brickner W M: Brachial Plexus Pressure by the Normal First Rib, Ann. Surg 85 8?? 1927
Keen W W The Symptomatology Diagnosis and Surgical Treatment of Cervical Ribs Am. J M Sc 133 1?3 1907
Lewin, Philip: Arthrogryposis Multiplex Congenita, J Bone & Joint Surg 7 630 192?
Lowman, C. L.: The Use of Fascia Lata in the Repair of Disability at the Wrist, J Bone & Joint Surg 12 400 1930
McFarland B. Congenital Dislocation of the Head of the Radius, Brit. J Surg 24 41 1936
Milch H: So-Called Dislocation of the Lower End of the Ulna Ann Surg 116 28? 1942.
Naffziger H C., and Grant W T: Neuritis of the Brachial Plexus Mechanical in Origin The Scalenus Syndrome Surg Gynec. Obst 67 72? 1938
Ochsner A., Gage, M., and DeBakey, M: Scalenus Anticus (Naffziger) Syndrome Am. J Surg 28 669 1935
Telford E. D., and Stopford J S B.: The Vascular Complications of Cervical Rib Brit. J Surg 18 557 1930-31
Thompson C. F., and Kalayjian B.: Madelung's Deformity and Associated Deformity at the Elbow Surg Gynec Obst. 69 2?1 1939
White J R. A: Congenital Dislocation of the Head of the Radius Brit. J Surg 30 3?? 1943.

AUTHORS' INDEX*

*To facilitate finding the correct volume referred to the page numbers of each volume are printed at the top of each page of the index.

AUTHORS' INDEX*

*To facilitate finding the correct volume referred to, the page numbers of each volume are printed at the top of each page of the index.

C

D

N

O

P

SUBJECT INDEX*

A

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*To facilitate finding the correct volume referred to, the page numbers of are printed at the top of each page of the index.

B

C

F

G

H

I

J

Q

R

S

U